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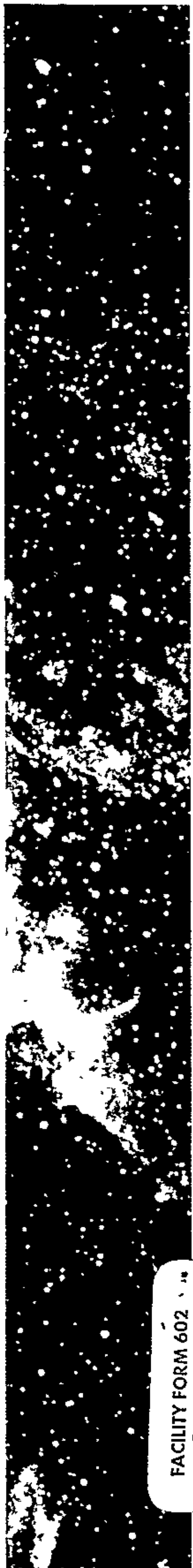
SPACE SYSTEMS



DEVELOPMENT OF A PROTOTYPE WASTE COLLECTION SYSTEM

(THE MODIFIED HYDRO JOHN)

PREPARED BY

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SPACE SYSTEMS
SPACE DIVISION
GENERAL ELECTRIC COMPANY

UNDER

CONTRACT NAS 9-9741

D. Hughes - Technical Monitor

FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

GENERAL ELECTRIC

CR-115040

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF ILLUSTRATIONS

1.0 SUMMARY

The Modified Hydro John is a fecal waste management system which combines the salient features of two previously developed concepts. The feces are disposed of and stored as in previous "Dry John" systems. An anal flush replaces the use of toilet tissue as in previous "Hydro John" systems.

The Modified Hydro John is completely automatic and is designed for use in either zero or one gravity environment.

The operation of the system consists of four basic steps in sequence: collection of the solid matter; pumping of the solids to a storage container; anal flushing and drying; and vacuum drying of the solid matter in the storage container.

The system was designed, developed, and tested for the National Aeronautics and Space Administration - Manned Spacecraft Center located in Houston, Texas, under Contract NAS 9-9741, with the General Electric Company, Life Systems Operation, located at Valley Forge, Pennsylvania.

2.0 INTRODUCTION

2.1 Background

During the past years, the General Electric Company has developed two basic approaches to the design of feces management systems for space application.

In one approach, the Dry John, the feces and toilet tissue are collected, treated, and stored immediately below the toilet seat area.

In the other approach, the Hydro John, the toilet tissue is replaced by warm water flushing and air drying. The water is then mixed with the feces and pumped out to the spacecraft water recovery system.

The Dry John is mechanically less complex, but requires the continuous expenditure of toilet tissue. Also, because of the tissue usage, there is more potential for contamination than with the Hydro John where the hands of the user are not exposed to the anal area directly or indirectly.

The Hydro John has one complicating factor in that water is mixed with the fecal solids. The resulting slurry has to be eventually treated and recovered for rinse somewhere downstream in order to maintain the water balance in a typical spacecraft life support system.

In the Modified Hydro John described in this report, the fecal solids are pumped from the collection chamber into a Dry John type storage container prior to the admission of the anal flush water. In this manner, the solution of fecal solids into the water stream is kept to a very minimum. The water can also be used more effectively to rinse the internal surfaces of the system since it is relatively clean.

The Modified Hydro John program evolved as an improvement on the prototype Hydro John system developed under Phase I of Contract NAS 9-9741 as described in the final report dated February 25, 1970. The system was designed to handle both urine and feces. The purpose of the Modified Hydro John is to demonstrate the capability of separation of the feces from the urine and wash water in a typical Hydro John system.

Three basic concepts were tested and evaluated during a preliminary design phase. These tests and evaluations were described in a final report which is attached in the appendix.

The final design for the Modified Hydro John was selected during an in-house design review attended by the NASA technical program monitor. The design combines the most desirable features of the proposed concepts #2 and #3 described in the attached report.

2.2 Requirements

The Modified Hydro John system was designed, developed, fabricated, and tested to meet the following requirements:

1. The system must be capable of separate collection and disposal of solid feces and anal flush water.
2. Anal flush water must be used to rinse the feces collection chamber.
3. The equipment must be designed so as to keep the mixing of fecal solids with the flush water to a minimum.
4. The design shall be compatible for operation in a zero "G" and one "G" environment.
5. The seat must be self-centering, relatively comfortable and easily cleaned.
6. The anal flush and air drying must be capable of comfortably cleansing the user to a degree where no other auxiliary expendables such as toilet tissue are required.
7. The system must be capable of operation on an air flow of 10 to 20 cfm and a flush water input of 4 pounds maximum.
8. The system must be easy to operate.
9. The system must be easily maintainable.

10. The system must be capable of storing the collected feces in a bacteriostatic condition by vacuum drying.

11. The volume of the storage container shall be capable of accommodating approximately 120 usages.

12. The system must not dissipate objectionable odors.

13. All the electrical power must be derived from 28 Volt DC or a 200 Volt, 3 Phase, 400 Cycle interface.

14. All pneumatic equipment is to operate on a minimum of 60 psig pressurized gas source.

15. Consideration must be given to minimizing the system weight, volume, and power requirements. However, no design optimization is required.

3.0 SYSTEM DESCRIPTION

The physical configuration of the Modified Hydro John is shown in Figure 1. The general internal make-up of the system is depicted in the schematic diagram in Figure 2.

There are three basic subsystems: the Modified Hydro John proper with the collection chamber, anal flush, phase separator and auger; the feces storage container; and the warm water reservoir for the anal flush.

3.1 Overall Operation

The operation of the Modified Hydro John involves several operations which are automatically controlled by a programming timer. The user has a minimum of extraneous tasks to perform:

1. He has to turn a knob and open the cover enclosing the seat.
2. He may use a positioning jet to assure himself that he is properly located over the seat.
3. He has to push the flush switch at the end of defecation.
4. He has to close the cover when leaving the system.

The self-positioning design of the seat makes the use of the positioning jet unnecessary after several uses. The jets have been retained as a supplement to the warm air drying and a possible aid to stool separation in zero gravity. Without the positioning jets then, the use of the Modified Hydro John is not any more complex than the use of any typical toilet facility.

The system operates as follows:

With the cover closed, all the internal surfaces which are exposed to the excreta and flush water are sealed from the outside environment.

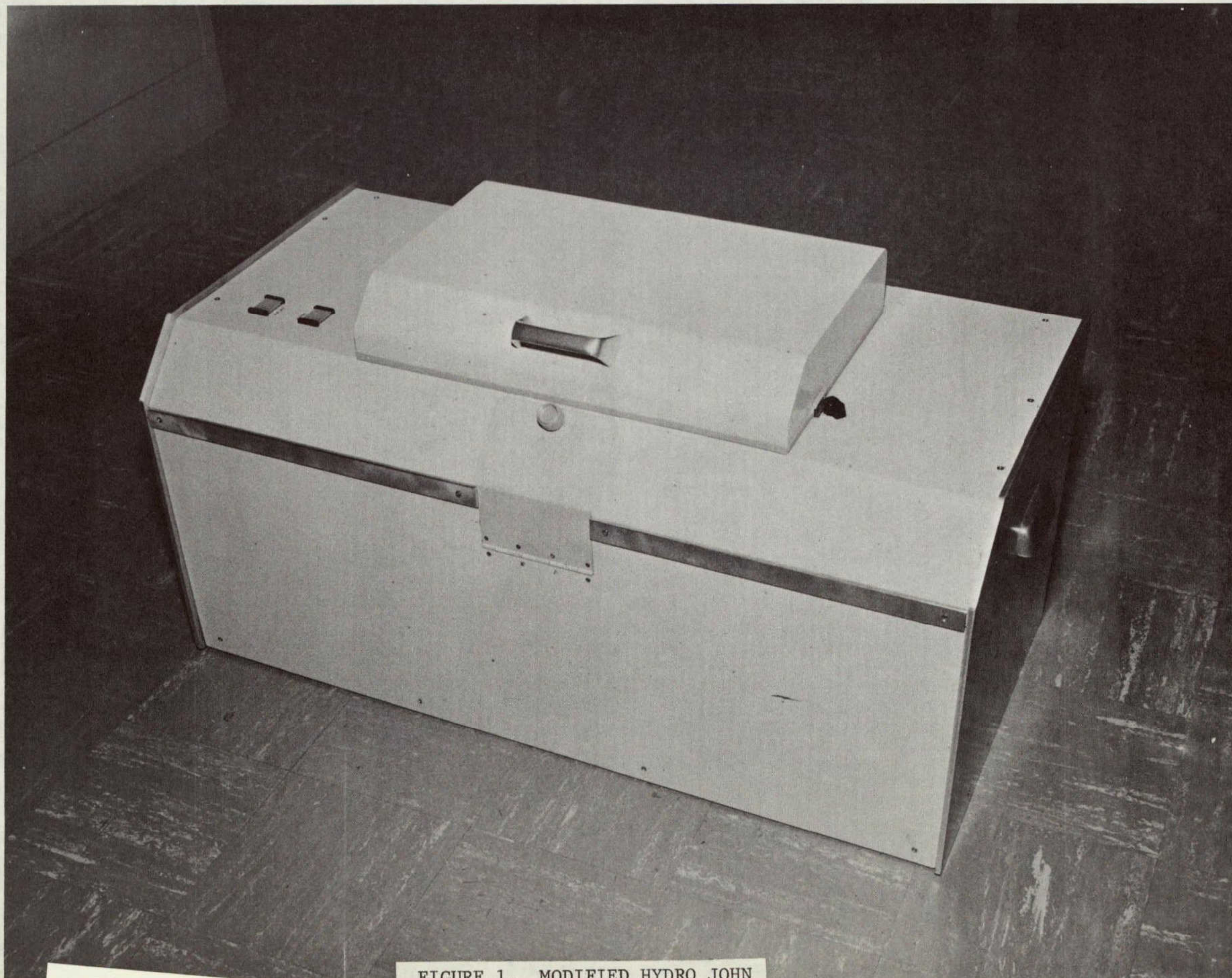
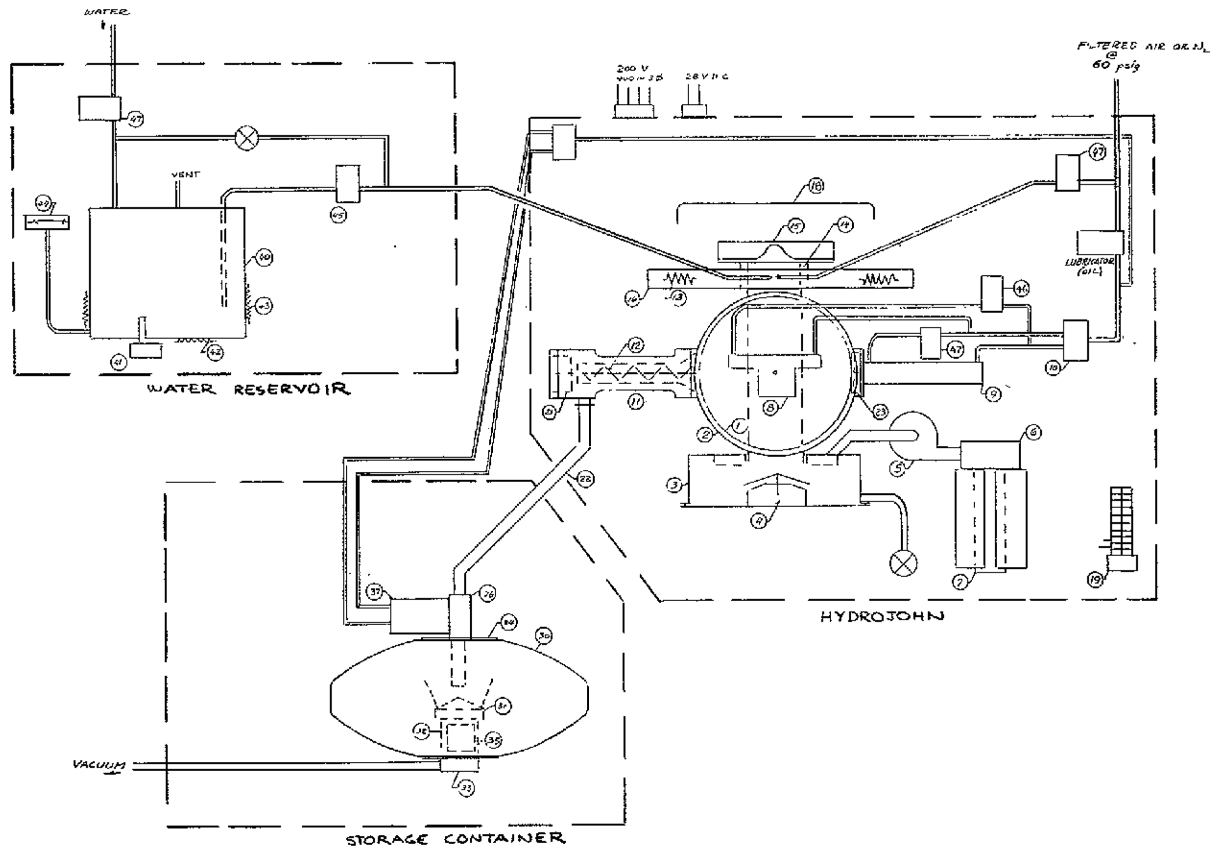


FIGURE 1. MODIFIED HYDRO JOHN

FOLDOUT FRAME 1

FOLDOUT FRAME 2



ITEM	IDENTIFICATION	PART NUMBER
47	SOLENOID VALVE	81DA1200 SKINNER
46	SOLENOID VALVE	82DA1175 SKINNER
45	GEAR PUMP	09-70-303 MICROPUMP
44	LEVEL SENSOR	LAB UNIT
43	STRIP HEATERS	
42	STRIP HEATER	75 WATTS - 110 AC
41	TEMP. CONTROL	C47 (UNITED ELECTRIC)
40	WATER TANK	(MADE FROM HARRIS FLOAT)
37	VALVE OPERATOR	ST 20 JAMESBURY
36	BALL VALVE	A36TT 3/4 JAMESBURY
35	SLINGER MOTOR	1/20 HP, 2700 FRAME INDUKT. - WELCO IND.
34	INLET PLATE	
33	BOTTOM PLATE	SK56197-811
32	MOTOR HOUSING	SK56197-812
31	SLINGER	
30	STORAGE CONTAINER	SK56197-810
23	PISTON	
22	INTERCONNECTION	
21	TORQUE MOTOR	T2955-A (INLAND MOTOR CORP.)
19	TIMER	RC5/B-12 (INDUSTRIAL TIMER)
18	COVER	
16	HEATER HOUSING	
15	SEAT	
14	ADAPTER	SK56197-814
13	AIR HEATER	SEF 10 CHROMALOX (250 WATTS)
12	AUGER	SK56197-823
11	AUGER HOUSING	SK56197-824
10	4-WAY VALVE	1616A2001 (ROSS)
9	AIR CYLINDER	A-R-1-10 (TOM THUMB)
8	ROTARY ACTUATOR	1-TIA-4090-A1 (TOM THUMB)
7.	AIR FILTERS	PETROSORB MULTIPOR .9 - PALL CORP.
6.	AIR PLENUM	SK56197-813
5	AIR BLOWER	19A1217 GLOBE
4	TORQUE MOTOR	T2955D - (INLAND MOTOR CORP.)
3.	PHASE SEPARATOR	SK56197-804
2	PISTON HOUSING	SK56197-821
1	ROTATING PISTON	SK56197-822

G.E. SPACE SYSTEMS KING OF PRUSSIA, PA.

MODIFIED HYDROJOHN SYSTEM SCHEMATIC

NASA CONTRACT NAS 9-9741

10-15-70

SK56197-800-A

FIGURE 2

When the cover is raised, exposing the seat, the air blower is actuated causing an air flow into the unit through the open inlet. The air exhausts through a filter assembly designed to retain odors and bacteria.

The seat is so designed that the only comfortable position is that which is the right position. The user may, in addition, use the positioning jet by pushing the "air jet" button. A gentle stream of air, of controllable intensity, is aimed at the ideal position of the anus so that the user can better position himself. During defecation, the stool is dropped into the vertical chamber of the rotating piston. Under zero gravity, the stool would be moved by the air flow which is directed from the seat to the bottom of the chamber and into the phase separator. The stool is retained by the network of holes at the bottom of the chamber, while the air flows through.

When the flush switch is energized, the following sequence of events takes place:

1. The vertical chamber is turned to horizontal.
2. The horizontal piston moves the feces into an auger at the forward end of the stroke.
3. The auger pumps the feces through a valve to a storage container.
4. In the storage container, the feces are thrown against the wall by a high speed rotating slinger. The feces are continuously vacuum dried between usages.
5. After disposal of the feces, the sliding piston is retracted and the collection chamber is returned to its normal vertical position.
6. A warm water spray washes the anal area.
7. The anal area is dried by a warm air flow.
8. The system automatically shuts down at the end of the cycle.

A detailed description of the operation is contained in the following paragraphs.

3.2 Detailed Description of Basic Modified Hydro John

The Modified Hydro John, excluding the storage container and the warm water supply, consists of the following items as shown in Figure 3.

1. Seat and Cover
2. Adapter and Accessories
3. Rotary Piston
4. Sliding Piston
5. Auger
6. Phase Separator
7. Blower
8. Filter Assembly
9. Heaters

3.2.1 Seat and Cover

The seat is all metal, black anodized, designed for self-centering and minimum cross-contamination among users. The selection of metal over the common "soft" materials was originally dictated by the need to avoid fire hazards in pure oxygen atmospheres. This seat configuration has been used and satisfactorily tested on previous General Electric systems. The seat is flanked by two holding handles. These handles would be used for tie-down in zero gravity application. The seat and the handles are enclosed by a gasketed cover. The cover prevents odors from diffusing in the cabin atmosphere while the system is not in use. See Figure 4 for illustration.

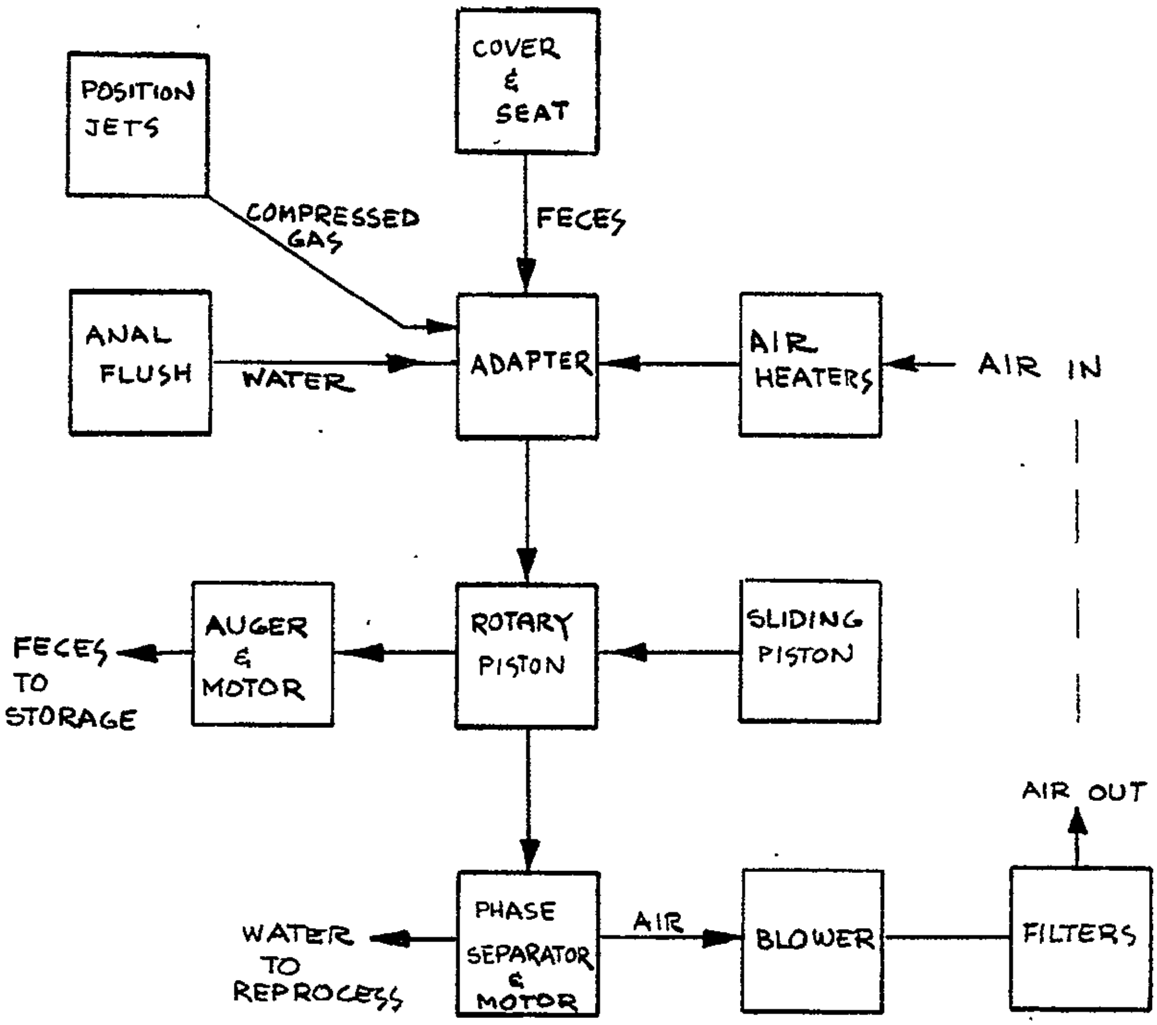


FIGURE 3

BLOCK DIAGRAM OF BASIC MODIFIED HYDRO JOHN.

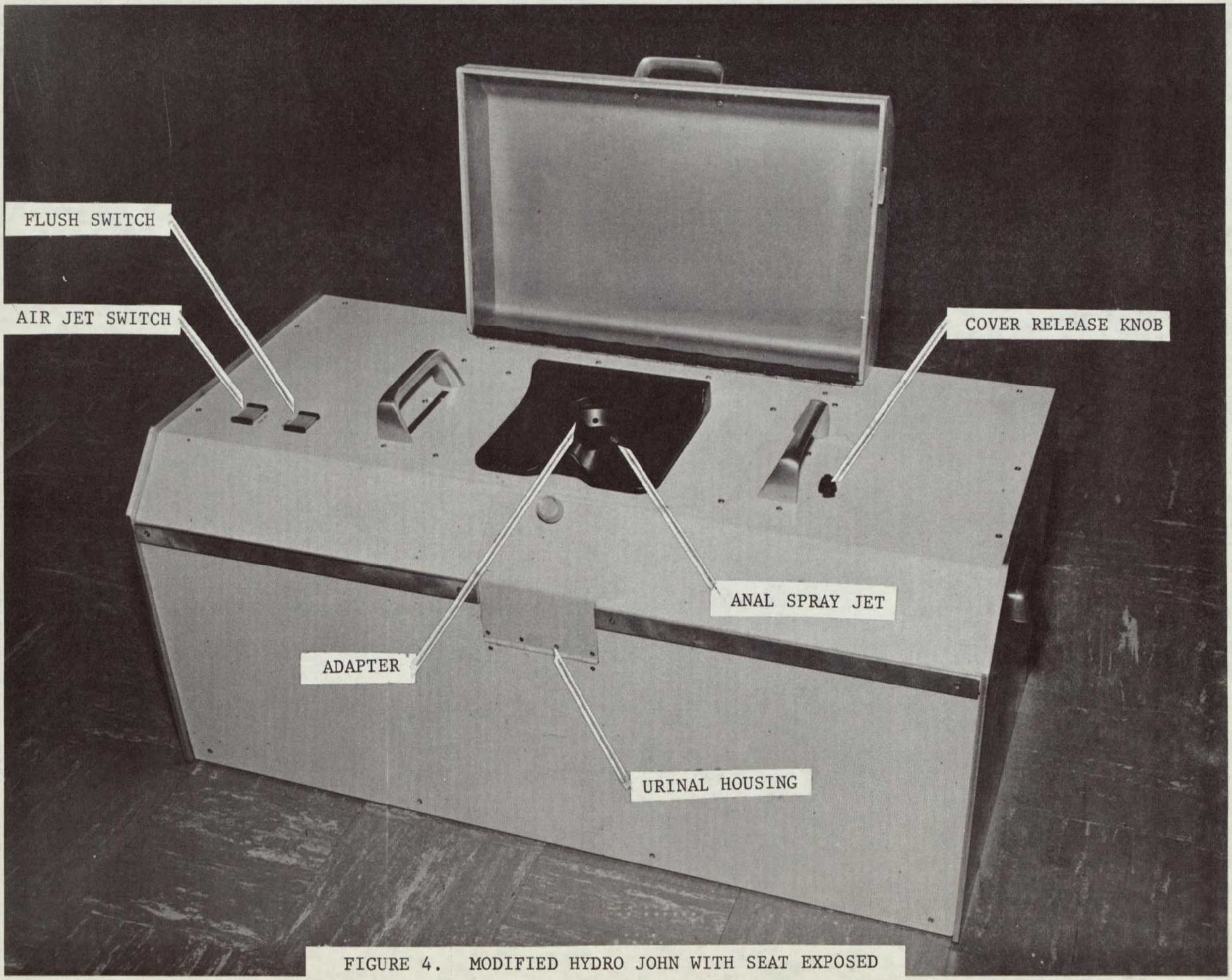


FIGURE 4. MODIFIED HYDRO JOHN WITH SEAT EXPOSED

3.2.2 Adapter and Accessories

The adapter, shown in Figure 4, connects the seat to the rotating piston. It has a series of orifices which exit immediately below the seat through which the air flows from the plenum below the seat into the collection chamber.

The adapter also has the orifices for the positioning jets and the anal spray nozzles.

The adapter can be disconnected by removing the adapter plate under the seat.

3.2.3 Rotary Piston

The rotary piston is located below the seat. See Figure 5. It has an internal bore four inches in diameter by nine inches long which can be positioned in either vertical or horizontal position.

In the vertical position, the bore is in line with the opening of the rotary piston housing, the adapter and the seat opening, at the top end,, and the perforation which connects to the phase separator at the bottom. This configuration is referred to as the collection chamber. In the horizontal position, the rotary piston bore is in line with the sliding piston on one end and the auger at the other.

Rotation of the piston is accomplished by a Rotary Pneumatic Actuator Model T1A4090A1 made by PHD Inc., Fort Wayne, Indiana, capable of a torque output ratio of 2.22 in.-lb/psi. The entire assembly is sealed with "O" rings to avoid ambient contamination.

The rotary piston assembly is made from standard extruded 6061T6 aluminum shapes, and Tufram coated for corrosion resistance, durability and smoothness of operation.

An exploded view of the rotary piston is shown in Figure 6.

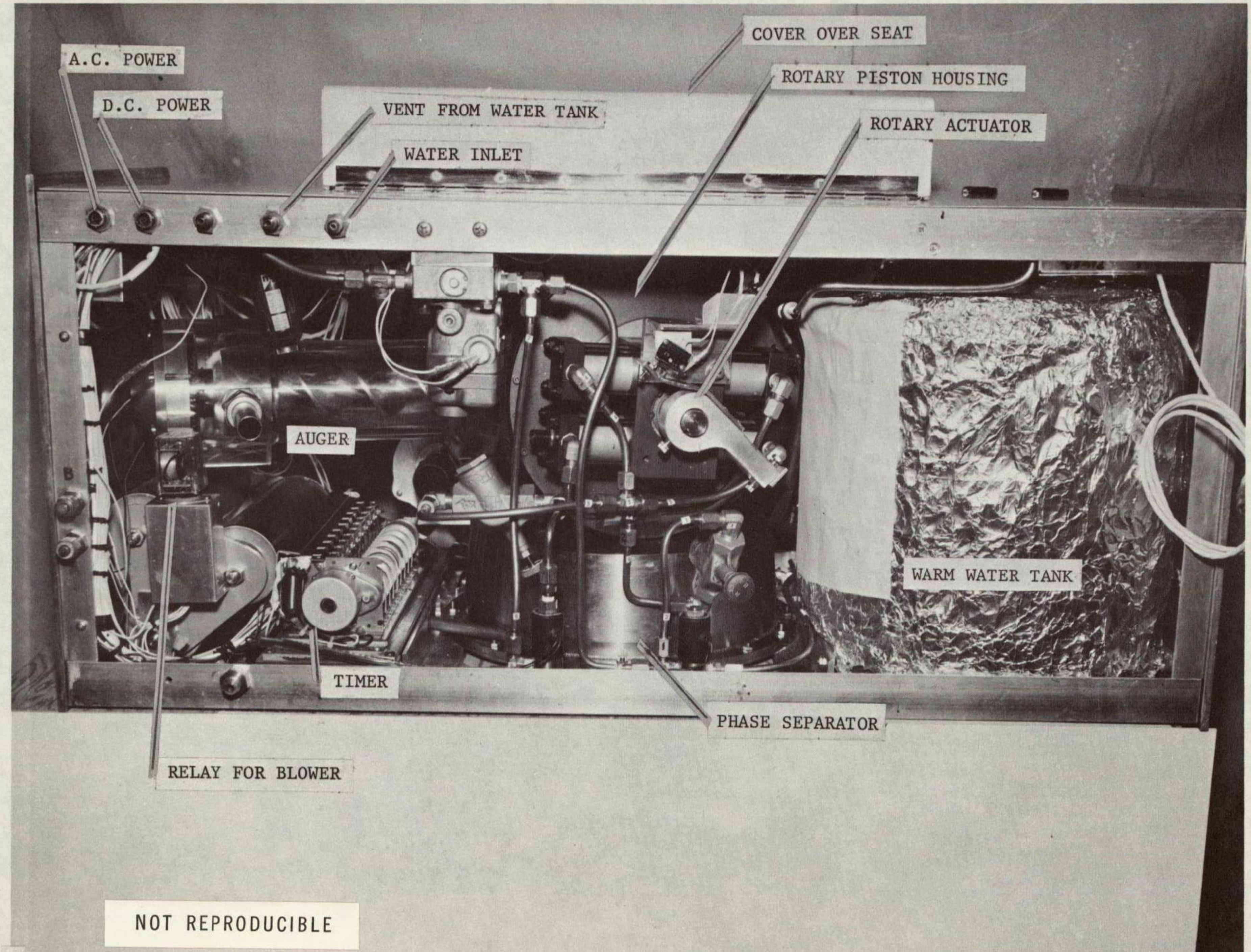


FIGURE 5. REAR VIEW OF MODIFIED HYDRO JOHN

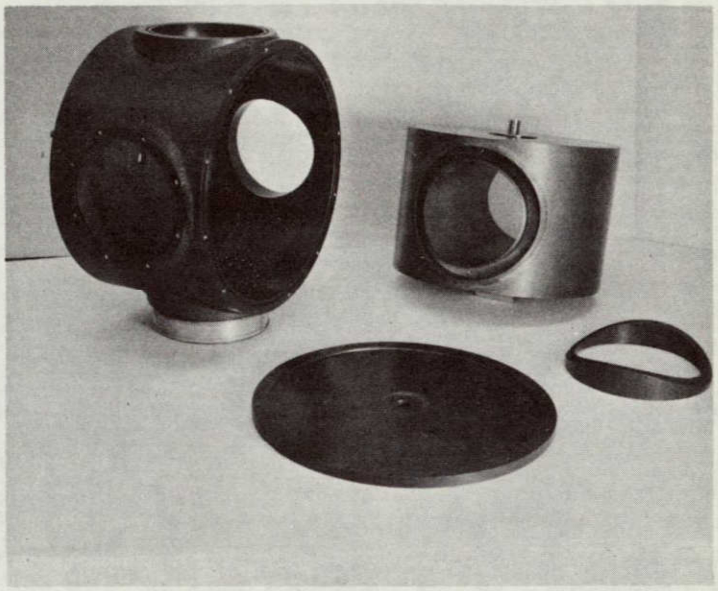


FIGURE 6. EXPLODED VIEW OF ROTARY PISTON

3.2.4 Sliding Piston

The function of the sliding piston is to pump the feces from the rotary piston into the auger. It consists of a relatively thin plunger with an "O" ring which contacts the rotary piston bore. The plunger is energized by a Tom Thumb double acting air cylinder type AR, also made by PHD Inc. See Figure 7.

3.2.5 Auger

The auger is basically a stainless steel screw, flared from a 2-inch diameter to a 4-inch diameter at the end facing of the rotary piston.

The screw is housed in a Plexiglas housing which also includes the auger drive motor. The drive motor is attached directly to the auger shaft and is separated by the auger chamber by an "O" ring seal.

The motor is a 28 volt D.C. torque motor, Model #T2955-D, made by Inland Motor Corporation, Radford, Virginia.

The auger is connected to the storage container by a 1-inch O.D. tubing. See Figures 5 and 7.

3.2.6 Phase Separator

The phase separator is required for the proper operation of the system during zero gravity environment. Air and flush water enter the unit through the openings at the bottom of the collection chamber. The flow is created by the blower connected to the air manifold in the phase separator. Air and water are integrated by the rotating blades of the assembly. The water is separated from the air by acceleration and centrifugal forces and collects on the internal wall of the housing

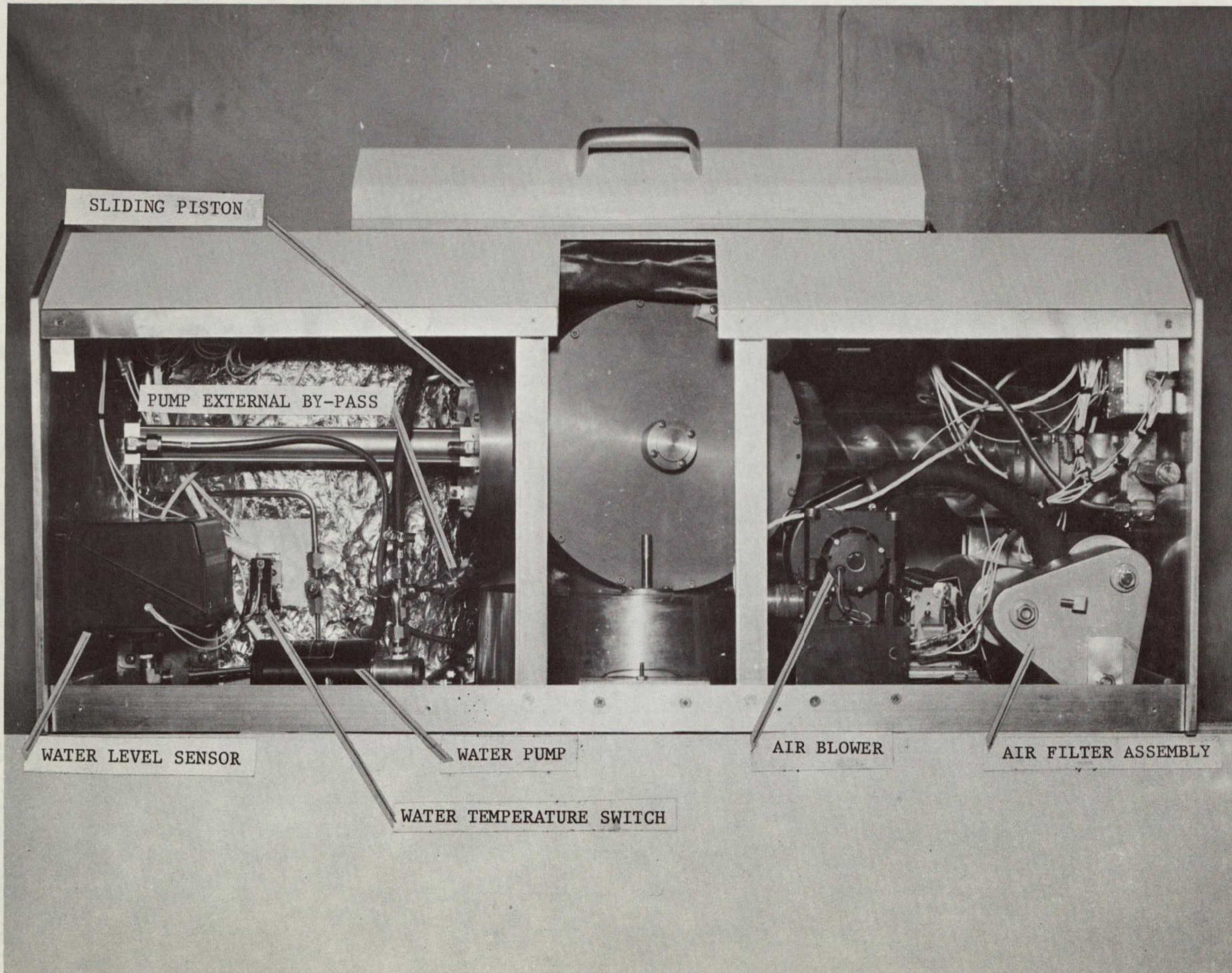


FIGURE 7. FRONT VIEW OF MODIFIED HYDRO JOHN

from which it is pumped out. The air returns to the blower through an annular plenum surrounding the inlet opening. The blade assembly is driven by a torque motor, Model #T2955-D manufactured by Inland Motor Corporation, Radford, Virginia. The motor is capable of a maximum torque of 10 lb.-in. and a no-load maximum speed of 67 rad/ second.

A drawing of the assembly is shown in the Appendix.

3.2.7 Blower

The physical characteristics of the blower and its performance data are shown in Figure 8. The support bracket has been slightly modified to fit the Modified Hydro John so as to minimize the length of the interconnection between the phase separator and the filter assembly. The blower is manufactured by Globe Industries, Dayton, Ohio.

3.2.8 Filter Assembly

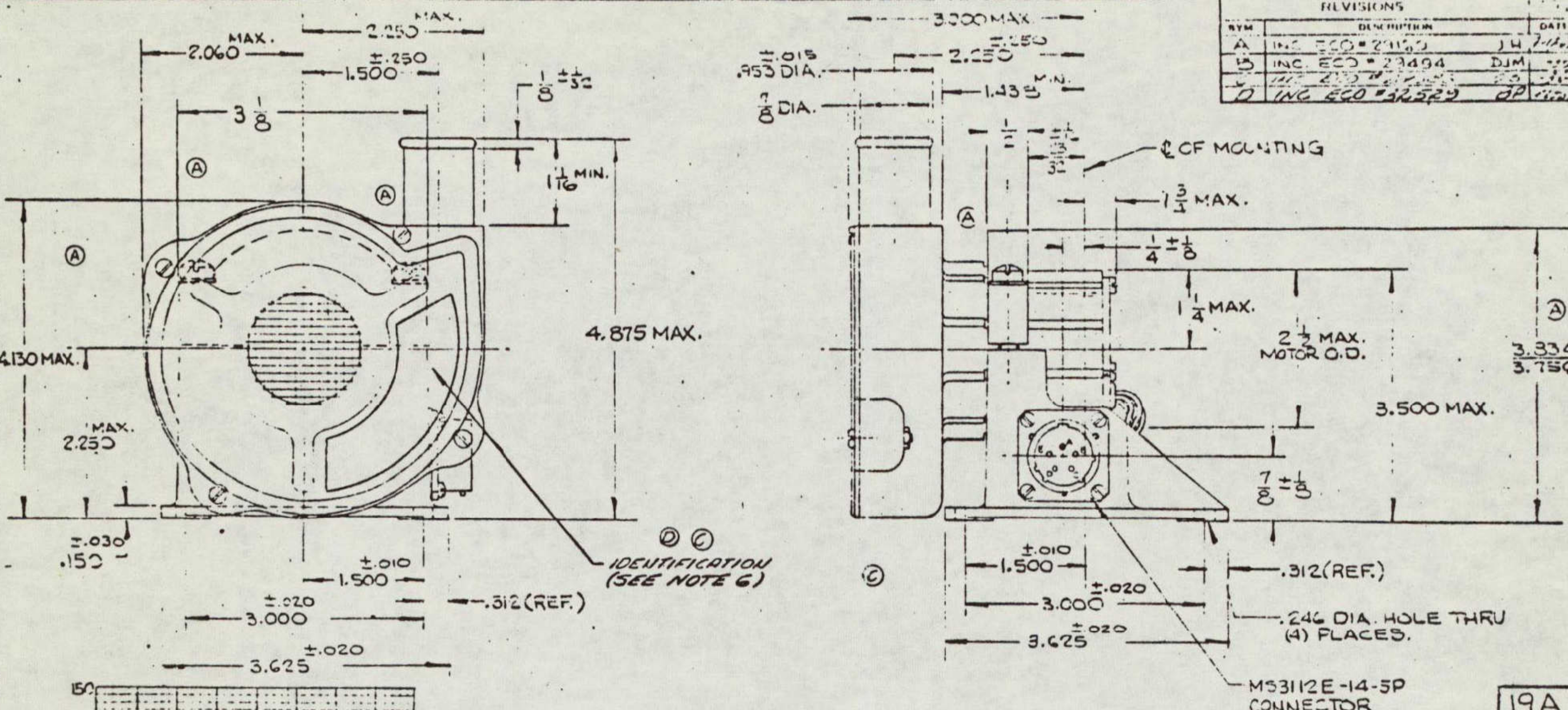
The filters are intended to remove odors and bacteria from the air flow exhausting from the system. The assembly consists of three filter cartridges mounted in parallel to a common plenum chamber. See Figures 5 & 7.

The cartridges, Part Number ACS 1001 CVH, are manufactured by Aircraft Porous Media, Glen Cove, New York, and are rated for 100% removal of particle sizes below .08 microns and for 98% removal of particles below .008 microns. The cartridges also contain a high grade activated carbon for odor removal (one pound of charcoal per cartridge).

3.2.9 Heaters

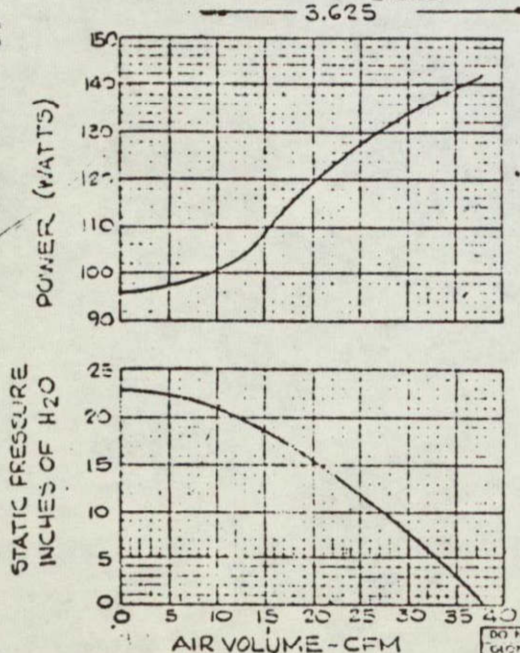
The heaters are mounted below the seat next to the adapter for the purpose of warming the drying air after the anal flush. The heaters are Chromalox finned elements rated at 250 watts each. They are connected in series and in line with a thermoswitch Type B52, United Electrical Controls, Watertown, Massachusetts.

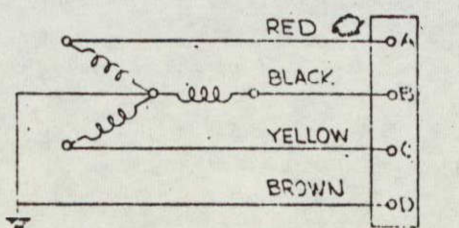
REVISIONS			
SYM	DESCRIPTION	DATE	APPROVAL
A	INC. ECO # 2[illegible] JH	[illegible]	[illegible]
B	INC. ECO # 29494 DJM	[illegible]	[illegible]
C	[illegible]	[illegible]	[illegible]
D	INC. ECO # [illegible] DP	[illegible]	[illegible]



19A1217

C





SCHEMATIC

A B C PHASE SEQUENCE FOR COUNTERCLOCKWISE ROTATION, VIEWED FROM INLET END

NOTES:
1. 200 VOLTS AC., 3 PHASE. 400 C.P.S.
2. MIN. SPEED: 18,500 RPM.
3. MAX. CURRENT: 0.65 AMPS.
4. ROTATION. SEE SCHEMATIC.
5. UNIT CONFORMS WITH MS 22053-4 (WEP).
6. *CONTRACT NUMBER TO APPEAR ON IDENTIFICATION PLATE, AS SPECIFIED ON GLOBE ORDER.*

FIGURE 8

REDUCED PRINT
ISSUED C/A
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ITEM	REQD	PART NO.	DESCRIPTION	UNIT WT	NEXT ASSY	USED ON
LIST OF MATERIAL					APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON FRACTIONS ± 1/64, DECIMALS ± .005, ANGLES ± 1°

MATL 20A1217
HEAT TREAT
COATING
DEMAG [illegible]
STDS-17[illegible] FIN. [illegible]
CHK [illegible] DATE [illegible]
ENGR [illegible]
APPD [illegible]
APPD

NAME: FAN, CENTRIFUGAL- AC, FC, IND, #503 WIND.

GLOBE INDUSTRIES, INC.
DAYTON, OHIO

DWG NO. 19A1217
SCALE FULL WT [illegible]
CODE [illegible] SHEET 1 OF 1

3.2.10 Anal Flush

Distribution of water from the anal flush is accomplished by means of two jets aimed at the anal area. The jets are mounted directly to the adapter and can be removed without disturbing the rest of the system. The parts are made from commercial spray nozzles and modified to fit the adapter configuration.

3.2.11 Air Jets

The positioning jets are produced by compressed gas exiting through two opposite orifices located in the adapter immediately above the anal flush jet. The jets are aimed at the anus and and are controlled by the "air jet" push-button switch on the right top side of the system enclosure. The amount of air can be regulated by a manual valve accessible from the back of the unit.

3.3 Feces Storage Subsystem

The feces storage subsystem consists of the following components:

1. The Inlet Valve Assembly
2. The Container
3. The Slinger Assembly

The subsystem is connected to the auger by means of a flexible 3/4 inch I.D. tubing. The exhaust side is connected to vacuum. See Figure 9. This is an "expendable" part of the system: it must be replaced or cleaned when filled.

3.3.1 The Inlet Valve Assembly

The inlet valve is normally closed. It is opened only during usage to allow the transfer of the material from the auger to the storage container.

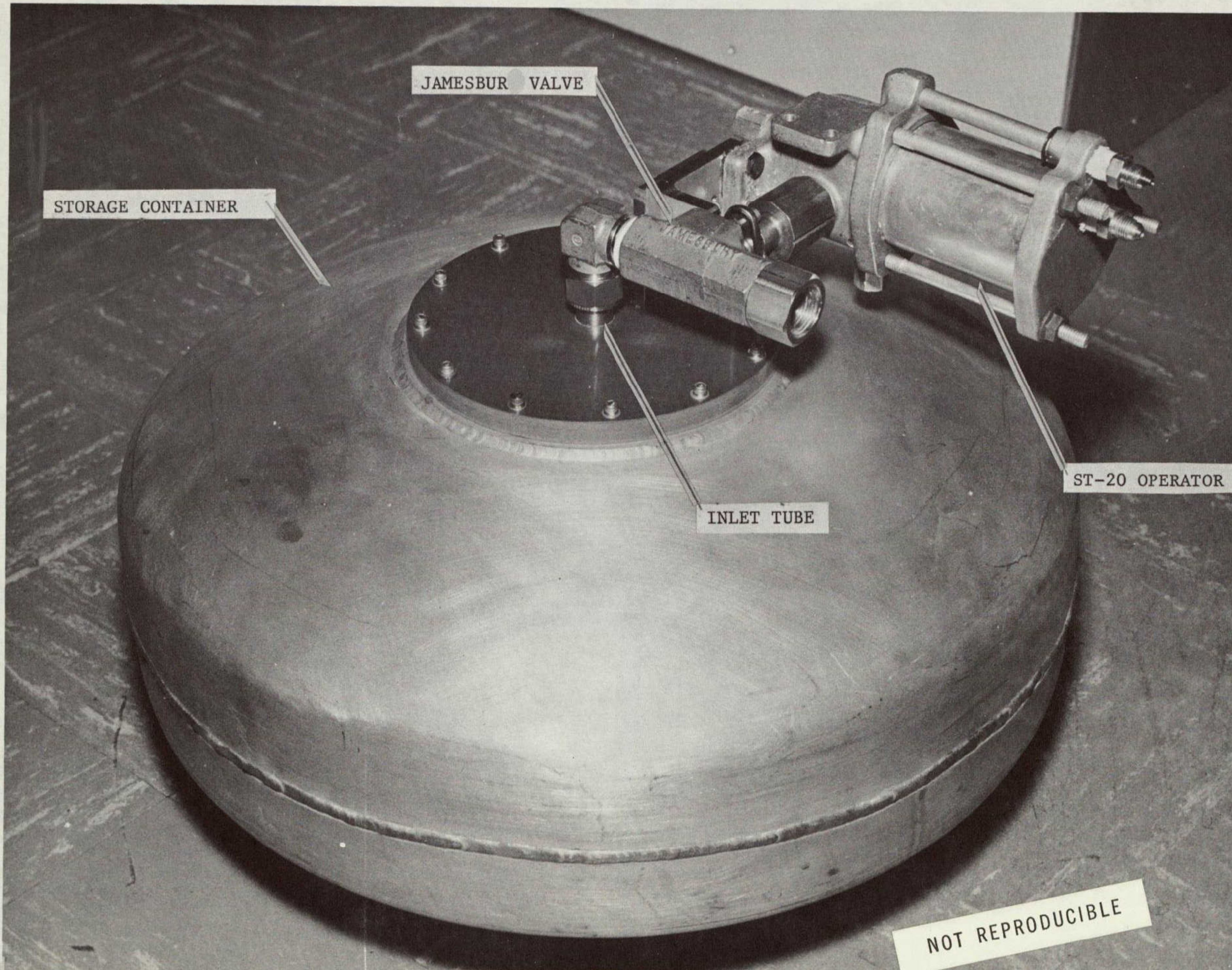


FIGURE 9. FECES STORAGE SUBSYSTEM

The valve itself is a 5/8" orifice ball valve, Part Number A36TT with an ST-20 remote operator manufactured by Jamesbury, Worcester, Massachusetts. See Figure 10.

The valve exits into the storage container through a stainless steel tube terminating above the surface of the slinger but below the slinger tines. This tube is connected to the aluminum body of the storage container by means of a Textolite plate. The non-metallic plate minimizes the conduction of heat and consequently, reduces the possibility of significant vacuum drying within the inlet tube.

3.3.2 The Storage Container

The storage container is a fabricated part made from two standard ASME flanged and dished heads welded flange to flange. The material is aluminum alloy 6061, 1/8" thick heat treated to T-4 condition after welding. The configuration of the container is optimized, to the degree of available standard shapes, for optimum collection efficiency. The storage capability exceeds 180 man days. See Figure 11.

3.3.3 The Slinger Assembly

The slinger assembly consists of a typical "Dry John" slinger plate with vertical tines, a motor, and supporting structure.

The motor turns the slinger at speeds of approximately 3,000 RPM. The motor is a 1/20 HP induction unit, frame #2700 made by Welco Industries, Cincinnati, Ohio.

The housing that holds the motor has the additional function of return duct for the air and moisture pumped out to vacuum. See Figures 12 and 13.

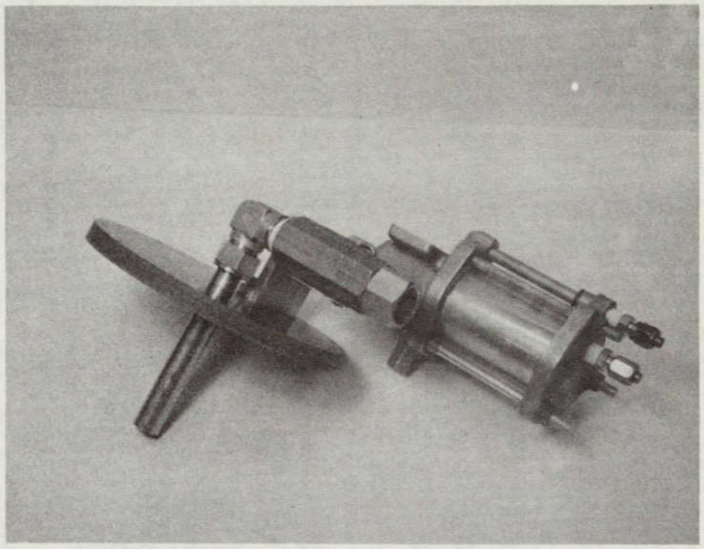


FIGURE 10. INLET VALVE ASSEMBLY

FIGURE 11. STORAGE CONTAINER

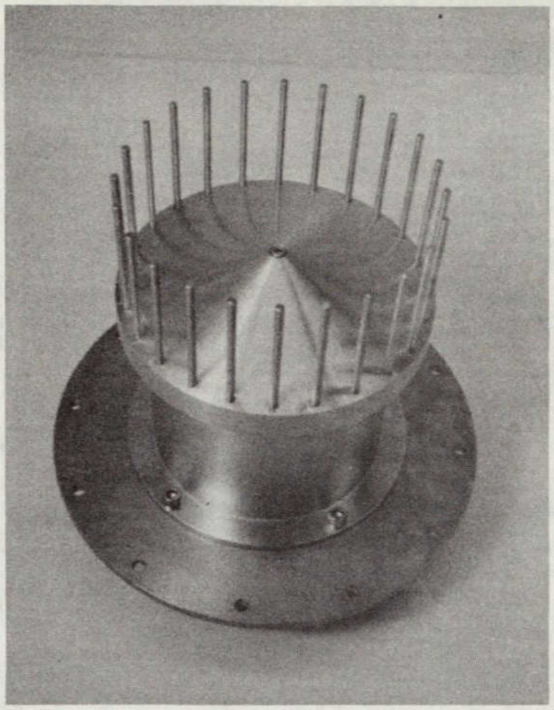


FIGURE 12. SLINGER ASSEMBLY

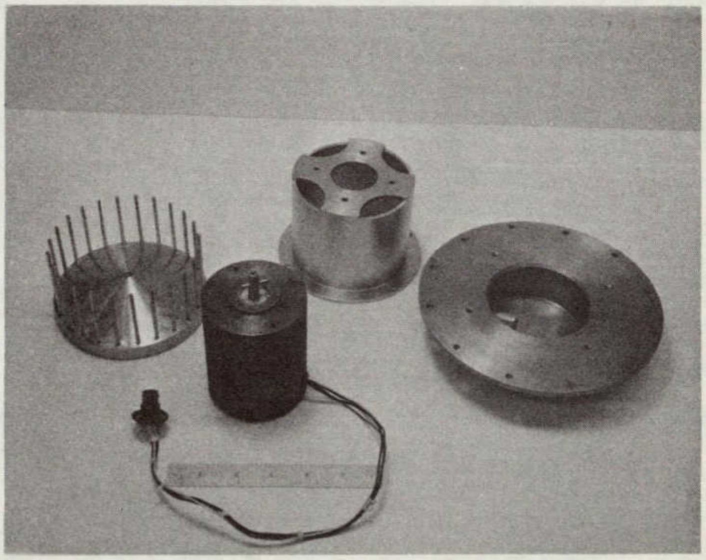


FIGURE 13. SLINGER ASSEMBLY COMPONENTS

3.4 Warm Water Supply

The warm water supply subsystem is designed strictly for laboratory type application and therefore not usable in zero gravity environment.

It consists of a holding tank, filling system, heating system and pump.

3.4.1 Holding Tank

The holding tank is made from corrosion resistant stainless steel, .05 inch thick with a working holding capacity of approximately three gallons. The general port arrangement of the tank is shown in Figure. 2.

3.4.2 Filling System

The filling of the tank takes place through the inlet valve, Part Number B2 DA 1175, made by Skinner Electric Valve, New Britain, Connecticut. The valve is normally closed. It is energized open when the liquid level in the tank falls to a height approximately two inches below the top of the tank. The level change is sensed by a pressure switch, JD300, Model 451, made by United Electrical Controls, Watertown, Massachusetts. The valve is de-energized when the water level reaches approximately one inch below the top of the tank. The water level can be varied by changing the setting in the pressure switch. See Figure 7.

3.4.3 Heating System

The water is heated by three silicone rubber strip heaters bonded to the outer surface of the tank. The heaters, Part Numbers 060100C1 (bottom of tank) and 030150C1 (cylindrical wall) are manufactured by Watlow Electric Company, St. Louis, Missouri. Each of the heaters is

connected to one of the phases and ground of the 200 volts, 3 phase supply. The total power is 750 watts, 300 watts for the bottom heater, and 225 watts each for the side heaters. The heaters are turned on and off by a thermoswitch with the sensing end protruding into the tank. The switch type C47, made by United Electric Controls, Watertown, Massachusetts, can be adjusted through a range from 0° to 160°F.

3.4.4 Pump

The water is pumped from the tank to the anal flush jet by means of a stainless steel leak-proof gear pump. The gear head is magnetically coupled to the drive motor and is capable of pumping one gallon per minute at a pressure slightly above 40 psig. The pump has an internal by-pass for minor flow variations; however, an external by-pass has been added to the system to adjust the flow to the capacity of the orifices at the 40 psig level. If the pressure is exceeded, the pump will uncouple (internally) while the motor keeps running at no load. With the external by-pass, some of the water can be returned to the tank thus regulating the flow through the orifices. See Figure 7.

The pump, part number 09-70-303, is manufactured by the Micropump Corporation, Concord, California.

3.5 Control System

The controls for the Modified Hydro John are automatic and are diagrammed in Figure 14. All the power is derived by either a 28 volt DC or a 200 volt, 3 phase, 400 cycle source. As can be seen, most of the functions are performed by a single cycle timer with ten switches, part number RC-5/B-12 made by Industrial Timer, Incorporated, Parsippany, New Jersey.

FOLDOUT FRAME 1

FOLDOUT FRAME 2

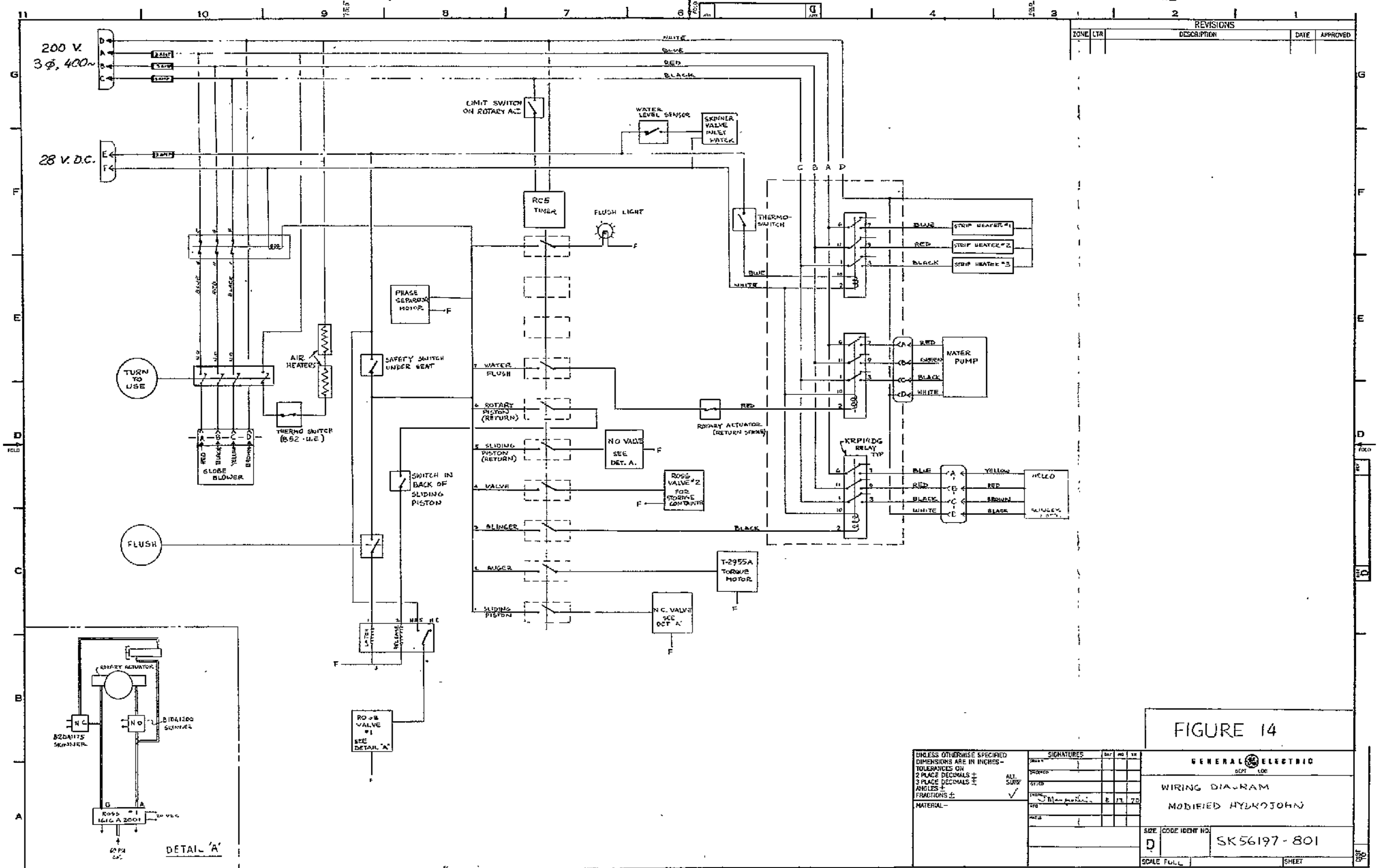


FIGURE 14

The system has several safety features. The first two are "external" safeties. The remaining are internal safety controls designed to avoid damage in case of malfunction:

1. In order to open the cover for usage, a catch switch must be turned. This switch turns the blower on and the air heaters on.
2. There is a safety switch under the seat that cuts the power off to all moving parts unless the user is seated.
3. The flush cycle cannot start unless the vertical chamber has rotated to the horizontal position.
4. The sliding piston cannot be energized unless the bore in the rotary piston is in the horizontal position.
5. The bore in the rotary piston cannot be returned to vertical unless the sliding piston is fully retracted.
6. The warm water spray cannot be started unless the vertical chamber (bore) in the rotary piston is in the proper position.

When the "flush" switch is energized, a latching relay causes the Ross valve (#1) to be energized. See Figure 14. This opens port "B" to pressure and "A" to vent causing the rotary actuator to turn. At the end of the 90° turn, a limit switch closes starting the programming timer cycle. At this time, Switch #1 opens a N.C. Skinner Valve letting pressure from port "B" to the sliding piston. The other switches are also energized in sequence to perform the functions described in paragraph 3.1.

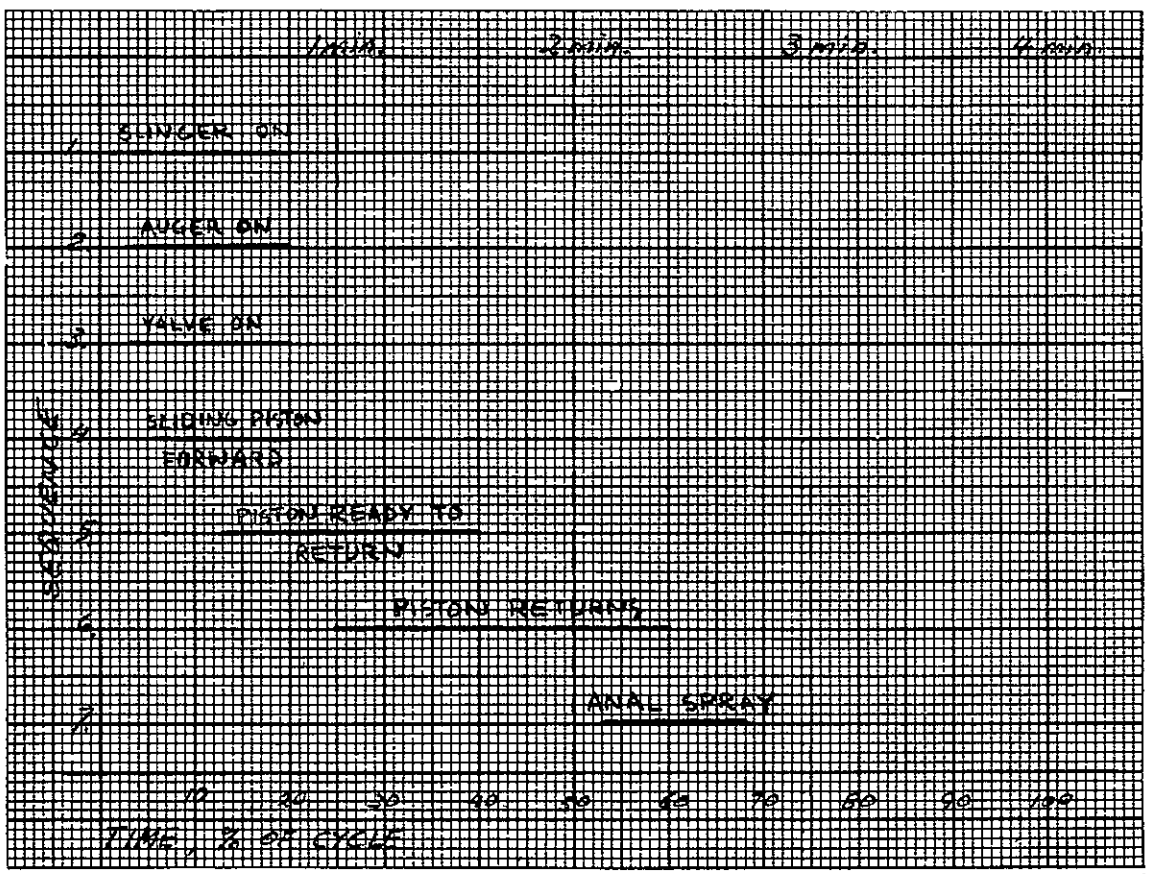
The return of the rotary piston is accomplished again by a combination of the same Ross Valve and a N.O. Skinner Valve. Before de-energizing the Ross valve (in this configuration A is open to pressure B is vented), the Skinner valve in line with the rotary piston is energized (closed). When the

Ross valve is energized, only the sliding piston moves. Only after this piston is fully retracted, the N.O. Skinner valve is de-energized, allowing pressure to the rotary piston return port.

The selection of a 400 cycle power system was made to facilitate the test of the unit on aircraft power. The 28 volts was used for the convenience of operation of torque motors and valves.

It should be noted that all the power going through the switches on the programming timer, except for the operation of the timer motor, is from the 28 V.D.C. source.

The sequence of events controlled by the timer is as follows:



The above time cycles are only tentative and can easily be reset as required by additional testing.

4.0 INTERFACES

The Modified Hydro John is packaged into a volume approximately 37 inches long x 17 inches high x 18 inches deep. This volume includes the warm water storage system. The feces storage container is a separate unit and can be located anywhere in the immediate vicinity provided that the length of connecting line is held to a minimum. Because of the two separate packages, there are two types of interfaces: the interfaces between the storage container and the major Hydro John unit (internal interface), and the interface between the system and the external support equipment. For illustration of the interface locations, see Figure 5.

4.1 Internal Interfaces

4.1.1 Electrical

A PT06P-8-4S connector with a 4 foot cord extending from the rear right upper corner of the main unit provides the power to operate the slinger motor.

4.1.2 Mechanical

A 3/4 inch I.D. Tygon line connects the auger to the valve at the inlet of the storage container.

4.1.3 Pneumatic

Two AN 832-4S fittings labeled port "A" and "B" provide the pressurized gas to operate the inlet valve when connected to the respective ports on the valve actuator.

4.2 External Interfaces

4.2.1 Electrical

A PT06-8-2S connector is required to provide the 28 V.D.C. power. The circuit has an internal fuse rated at 3 amp.

A PT06-8-4S connector is required to provide the 200 V, 400 cycle, 3 Ø power. Each phase has an internal fused rated at 3 amps.

4.2.2 Vacuum

A 1/2 inch NPT female thread is provided at the bottom of the storage tank for the vacuum line connection.

4.2.3 Pneumatic

Pressurized air/nitrogen is required for the operation of the air cylinders and air jets. The gas must be clean and oil free. An internal lubricator is provided with the unit for the lubrication of the air cylinders only. Connection is made through an AN832-4S type fitting. Pressure should be regulated at 60 psig.

4.2.4 Mechanical Miscellanea

Water is required for the refill of the flush water tank. Filtered water should be used. Inlet pressure should not exceed 60 psi. Gravity fill is possible. Note: Tank refills automatically. It will not fill or refill unless the 28 V.D.C. power is on. The water connection is made through an AN832-4S fitting. A similar fitting is provided to vent the tank to ambient.

A drainage connection is required for the urine and flush water. The drain level must be below that of the phase separator. An AN832-6S fitting is provided for this purpose.

5.0 USE PROCEDURE

The system is completely automatic so that a minimum of effort is required by the user.

Assuming that the system's interfaces are connected and in proper working condition, the user:

1. Rotates knob located on top of the unit, see Figure 4, to permit opening of the lid over the seat, and turns the cover to the back.
2. Seats himself over the inlet opening and remains in a position in which the anal area contacts the entire surface of the seat. The user may use the air jet to check his position.
3. After defecation, the user pushes the "flush" switch which initiates the automatic disposal of the feces, the anal flush, and the drying sequence. Cleaning and drying may be further assured by a slight controlled motion of the anal area over the flush water stream and by partially unseating during the drying phase to facilitate the removal of the wet ring that forms at the parting line between the seat and user's skin.
4. Uses air jets to assure complete drying.
5. Returns lid in place and locks it by turning switch counter-clockwise.

6.0 OPERATIONAL CHECKS AND MAINTENANCE

6.1 Operational Checks

Due to the relative complexity of the system and the limited amount of testing on several of the newly designed components, it is suggested that periodic checks be made to assure that the system is in working order.

The simplest check can be made by mechanically actuating the rotary piston. This is done by pushing the recessed poppet below the valve. See Figure 5. The piston should rotate 90° then go back when the pressure on the poppet is removed. This is a simple check and is suggested to be used if more than 24 hours have elapsed between usages. A complete operational check can be made by turning the seat up and locating a Plexiglas plate with a gasket across the opening. The safety switch must be held in the energized position. Note that when this switch is on, the phase separator is on. The turning of the phase separator blades, although not noisy, is distinct and audible.

With the temporary cover over the adapter, the system can be put through a "flush" cycle. It is possible to visually check all the sequential operations of the system.

6.2 Maintenance

The system requires a minimum amount of maintenance. It is estimated that the storage container is capable of collecting the input from approximately 180 usages. The container must then be removed and cleaned or replaced. See next section for description. This change should be simultaneous with a general cleaning and flushing of the entire system, and a change of the three air filters. It is also suggested that the seat surface be periodically swabbed and rinsed with a disinfectant.

6.3 Cleaning and Disassembly

The following procedures are recommended for periodic cleaning and flushing of the system.

6.3.1 Flushing the Phase Separator

Open the cover and return cover release knob to closed position to turn blower off.

Introduce detergent and or disinfectant through seat opening in quantities of approximately a quart or less.*

Apply pressure on seat to energize phase separator. The solution is thus slushed inside of the phase separator and pumped out. Repeat and rinse as required.

6.3.2 Flushing the Auger

Connect water hose to fitting on auger housing. See Figure 15. Separate tubing connection at valve on storage container. Cap open end on valve. Connect tubing from auger to a suitable drain and flush water through. Auger may be energized by applying power (28 V.D.C.) directly to the red and black leads exiting from the auger. The auger can be made to turn in either direction by switching the leads connection. The auger and the line should clean within a few minutes.

6.3.3 Cleaning the Storage Container

Remove both end plates from the storage container and cover with plastic bags. Since the stored feces is vacuum dried, there should be no propagation of offensive odors. Care should be taken not to let the material get wet in order to maintain this inactive status.

The feces should become easily loose and removable in solids sections. The container can be flushed, sterilized, and reused. The top plate and lower plate assemblies can be soaked in a disinfectant solution

*A solution of Wescodyne manufactured by West Chemical Products, Inc., 42-16 West Street, L.I. City, New York was used during our laboratory tests.

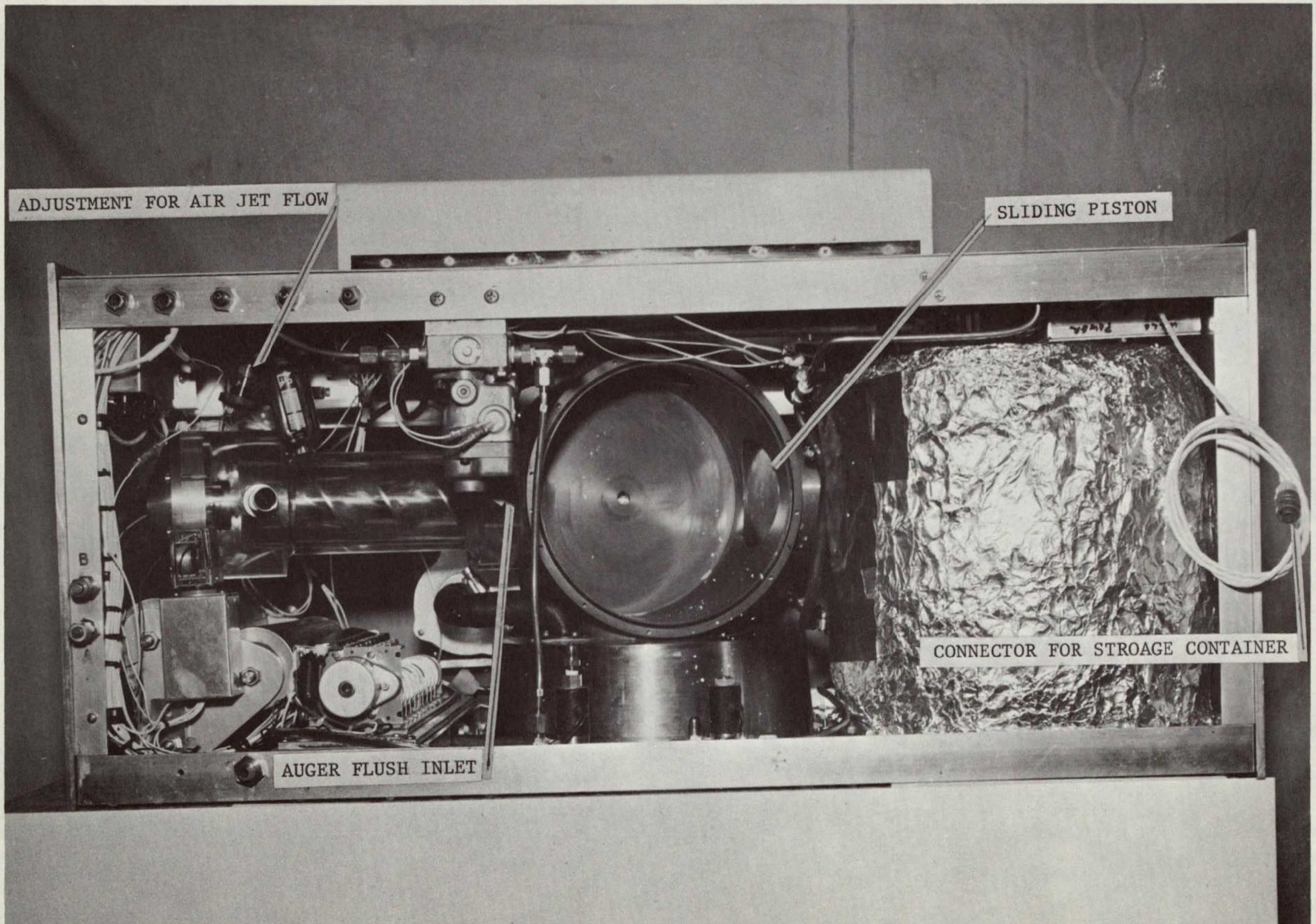


FIGURE 15. MODIFIED HYDRO JOHN PARTIALLY DISASSEMBLED FOR CLEANING

(such as Wescodyne) after removing the slinger motor and the air piston, then flushed, rinsed, dried and reassembled.

6.3.4 Cleaning the Rotating Piston

The rotating piston can be partially cleaned by lightly spraying the cleaning liquid over the surface of the rotating drum as the part is being turned slowly by hand after disconnecting the pressurized gas. A more thorough cleaning can be accomplished by disconnecting the rotary actuator from the valve, removing the screws that hold the end plate to the piston housing, then pulling the entire subassembly out. This leaves the housing cavity exposed thus facilitating the access to all the surfaces contaminated by fecal material. See Figure 15.

7.0 TEST RESULTS

The purpose of the test was to demonstrate the performance of the Modified Hydro John under actual usage condition by several persons over the period of one week, according to the Test Plan dated 19 October 1970, and attached in the Appendix of this report.

The description of the test results will follow the same outline and sequence of the Test Plan.

7.1 Subsystem Tests

The subsystems tests were conducted on the individual functional assemblies prior to their interface with the complete installation.

7.1.1 Storage Container

The feces storage container was checked out without any difficulty. It is to be noted that this is the only subsystem which has not been subjected to any major redesign from previous configurations.

The first test was an electrical checkout to make sure that the slinger turns smoothly when power is applied to the system. The container was then checked for leaks, first by pressurizing to 15 psig and using "snoop" as a detector, then by evacuating with a Welsh Vacuum pump and observing the loss of vacuum over a period of one hour. With a mercury manometer, the recorded pressure change was less than .10 inch of Hg over the one hour period.

7.1.2 Warm Water Reservoir

The warm water reservoir was extensively checked as part of the complete anal spray subsystem, including the pump and the sprays. Tests were performed on the pressure switch and the temperature switch and found to be satisfactory. The pressure switch is set to control the water to a level between one inch to two inches below the top of the tank.

The temperature switch is set to keep the water to slightly above body temperature. However, it can be easily reset after removing the front panel. The tank and connections were checked for leaks and found to be satisfactory.

7.1.3 Seat and Anal Flush

Several simulated tests were performed to checkout the efficacy of the sprays using peanut butter on a contoured rubber surface. It was found that a clean surface could be obtained with less than 300 cc's of water spray at pressures of approximately 30 psig.

Tests were performed on the pump. It was found that the pump could operate at pressures of 60 psig with a flow of 1200 cc's/minute. The flow rate increased to 2000 cc's/minute at 40 psig and 3300 cc's/minute at 30 psig. The pump is a gear pump and the changes are due to the operation of the internal by-pass. An external by-pass was added to permit a wider regulation in the flow of water from the pump. The pump is magnetically coupled and will stall if the flow exceeds the capacity of the system. When stalled, the pump gear uncouples from the motor, thus leaving the motor running at no load. It is recommended that this external by-pass be used to regulate the water flow from the anal spray jets. The adjustment valve can be seen in Figure 7.

7.1.4 Phase Separator

After initial difficulties due mainly to fabrication and assembly, the phase separator was put together and tested satisfactorily. The test consisted mainly in operating the unit at rated voltage and observing the water being pumped out at a pressure of approximately .50 psig.

7.1.5 Collection Chamber

The collection chamber consisting basically of the rotating piston and the sliding piston was initially checked and found to be working smoothly. The piston was rotated 90° by means of the rotary actuator several times and found to maintain a satisfactory degree of alignment and repeatability.

7.1.6 Auger Mechanism

The auger mechanism had been tested during the first phase of the program and found capable of pumping simulated feces consisting mainly of peanut butter and dog food mixtures. A new 2-inch diameter auger with a flared end was made to simulate the actual final design. The tests indicated that the system worked well when aided by suction from the evacuated storage container. To avoid possible stalling of the driving motor, a higher torque unit was installed.

7.2 System Tests

7.2.1 Mechanical Dry Run

After assembling the mechanical and electrical components and subsystems into a single system, tests were performed to check out the electrical operation of the various relays, valves, and heaters and the setting of the sequence of the timer. At this time, it was realized that the safety of the system would be enhanced if a safety switch were to be added under the seat so that the system can operate only when the user is seated over the inlet opening. The addition of this switch did bring some complications over the electrical control of the system; however, all the difficulties were overcome by a partial redesign of the circuitry.

Also, at this time, internal safety switches were added to prevent the rotary piston from returning to its normal vertical position unless the sliding piston is fully retracted, and to prevent the anal spray from turning on unless the rotary piston is back to the normal vertical position.

Mechanical tests were performed over a period of two weeks as some of the minor additions such as the safety switches were being made. The system performed satisfactorily except for a definite indication of increased torque requirement when operating the system after a relatively long period of inactivity, i.e., more than one day.

7.2.2 Simulated Usages

Several simulated usages were completed using the same peanut butter-Kenel burger mixture used in previous tests. During the second day of tests, the system failed. Failure was due to misalignment between the rotary piston and the sliding piston. The condition was precipitated by partial drying of some of the simulated feces near the "O" ring on the rotary piston causing a higher initial torque to be required to "break" the piston from the vertical position. Once the resistance was overcome, the rotating piston tended to overshoot the ideal horizontal position which is in line with the travel of the sliding piston. This overshooting was made possible by the play at the connection between the rotating piston and the rotary actuator. A visual inspection of the shaft showed considerable wear. It was decided to remake the part from hardened 440C stainless rather than the 303 which is relatively soft. In the meantime, the rotating piston was reset to continue testing. Special valves were added

between the rotary actuator and the solenoid control valve to slow-down the rotary motion by metering down the air flow into the cylinders. Additional tests with simulated feces were performed.

7.2.3 Manned Tests

Manned tests were conducted over a period of two weeks. The Test Plan originally required a one week test; however, the period was extended in the hope of attracting contributors. A total of nine usages were recorded. Only two men contributed. The main reason for the lack of participation is due to the absence of possible contributors from the laboratory area.

During the first three usages, it became obvious that a better control was required for the warm air temperature. The heaters were being energized by the timer on a fixed time basis and was adequate only if the usages were space sufficiently apart to allow a complete cool-down.

However, if the flush was started within one hour of the previous usages, then the air would be unconfortably warm. At this time, the two heaters were rewired in series and a thermostat was installed to control the "on-off" cycle. Also, the circuit was removed from the timer and attached to the same switch which is energized when the seat cover is open. This allows a longer time for the air to come up to temperature and produced very satisfactory results during the subsequent usages.

In all but one case, the anal flush was most effective. Napkins (separately disposed of) were used to check for cleanliness. In one case it appears that difficulties were caused by a long stool. The chamber had to be flushed twice. It is to be noted that, due to

several non-intrinsic reasons the length of the rotating chamber is only nine inches long which should accommodate most users. With the present hardware configuration, the only thing that can be done is to remind the prospective users that "brevity" is of the essence.

7.3 Post-Test Inspection and Evaluation

After the termination of the usage tests, the system was left inoperative for several days before the cleaning and shipping preparations were begun. It is important to note that there were no odors propagating from the system. Specific "sniffing" checks were made all around for this purpose.

The system was then flushed, cleaned and disinfected following the steps outlined in paragraph 6.3. All components had apparently remained in good working condition except for the rotating piston shaft which already was to be replaced based on previous evidence.

The additional significant observations were:

1. Some water had been drawn into the air return line.
2. Material drying at the elbow between the valve and the tube above the slinger.

The presence of the water in the air line was due to the suction created by the blower when the rotating piston is in the horizontal position. During this short time, the normal flow path is blocked and water droplets are drawn up into the air manifold from the drain line. This condition was corrected by automatically turning off the blower when the piston is horizontal.

The tendency of the feces to dry at the elbow was greatly increased by the fact that the usages were rare and that only a small amount of solids went through the line each day. Usages were spaced as far as 69 hours apart giving

ample time for total drying of any material up to the valve surface. This condition can be eliminated completely by removing the elbow and installing the valve vertical with the elbow between the valve and the auger if required. This depends mainly on the final installation of the equipment. Without the elbow, the drying in the inlet tube is made less of a problem by the consequent shrinkage and separation from the tube. This occurrence was quite evident in the visual inspection of the residue from the storage container.

7.4 Conclusions and Recommendations

The many tests performed on the Modified Hydro John have demonstrated the successful performance of the unit and the feasibility of this type of unit which combines the advantages of the Dry John and Hydro John type system.

The system is relatively more complex than either "Dry" or "Hydro" John; however, it offers many possibilities with a minimum of water contamination and flexibility in the treatment and disposal of solids.

There are many new design features and much more testing is required to evaluate the performance of the equipment and formulate any desirable change to improve its acceptability and reliability. For this reason, the basic design and assembly has been based on easy accessibility to any of the principal components wherever possible.

APPENDIX A

TEST PLAN

FOR

MODIFIED HYDRO JOHN

CONTRACT NUMBER NAS 9-9741

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

PREPARED BY: J. K. Mangiafardi, Engineer, Life Systems — DATE: Oct 19, 1970

APPROVED BY: R. W. Murray, Program Manager, Life Systems — DATE: Oct 13, 1970

GENERAL ELECTRIC COMPANY
SPACE SYSTEMS ORGANIZATION
Post Office Box 8555
Philadelphia, Pennsylvania 19101

1.0 SCOPE

The Modified Hydro John tests are to demonstrate the performance of the Modified Hydro John System under actual usage condition by several persons over a period of one week.

The tests will be limited to the operation of one development unit designed and built by the General Electric Company, Space Division, under NASA Contract Number NAS 9-9741.

2.0 OBJECTIVES

The main objectives of the test are to demonstrate that:

(1) The unit can be satisfactorily used to perform the function of a feces management system.

(2) The unit disposes of the fecal solids by pumping to a separate storage system without mixing with the anal flush water.

(3) The system is acceptable to the users with a minimum of training and conditioning.

(4) The system is physically safe to use.

3.0 EQUIPMENT TO BE TESTED

The equipment to be tested is the Modified Hydro John System consisting of the following major subassemblies:

(1) The commode which includes the seat, the adapter, the collection chamber, the phase separator, and the auger mechanism.

(2) The feces storage container.

(3) The flush water subsystem.

4.0 REQUIREMENTS

The primary requirement of the Modified Hydro John is to dispose of the fecal solids without mixing with the anal flush water.

The fecal solids are pumped by an auger type arrangement into a storage container.

Storage of the feces is to be accomplished by accumulation on the inner walls of the sealed container where the feces are vacuum dried and bacteriologically inactivated. A secondary goal of the Modified Hydro John is to improve the seat arrangement and the anal flush performance.

5.0 TEST SEQUENCE

The tests will be divided into two phases. During the first phase, the following subsystems will be checked out:

(1) The storage container

(2) The warm water reservoir

(3) The seat and anal flush hardware

(4) The phase separator

(5) The collection chamber

(6) The auger mechanism

The chronology of the tests will depend mainly on the availability of hardware. During the second phase, the entire system will be checked out in the following sequence:

(1) Mechanical dry run

(2) Simulated usage with substitute feces

(3) Actual manned use.

6.0 TEST DESCRIPTION AND PROCEDURE

6.1 Storage Container

The storage container assembly consisting of the container, the slinger and motor, the inlet and the outlet valves will be first subjected to an electrical check by operating the valves and the slinger motor several times to assure that they are in proper working condition. The assembly will then be checked for leakage by pressurizing it with the inlet and outlet valves closed. The pressure will be limited to 15 psig. A liquid spray such as "snoop" or equivalent will be used.

6.2 Warm Water Reservoir

The warm water reservoir assembly consists of the water tank, the pump, the outlet valve, the inlet valve, liquid level control, heater and heater control.

The assembly will be checked for leakage first, and then will be operated several times a day for a period of at least five days to assure that the selected water temperature is maintained and that the level of the water does not drop below the preset point for minimum possible excursion in water temperature.

6.3 Seat and Anal Flush Hardware

All the hardware above the collection chamber will be pre-assembled and tested to optimize the arrangement for a satisfactory anal flush. This includes the arrangement of the air heaters and the aiming of the water jets. The initial tests will be performed using a shaped silicone rubber cover over the inlet opening. The assembly will then be adapted to the laboratory toilet for direct use.

6.4 Phase Separator

The tests on the phase separator will be limited to leakage and to the operation of the impeller blades to assure smooth operation.

6.5 Collection Chamber

The collection chamber, consisting of the rotary plug, sliding piston, housing, and pneumatic controls will be tested to check the adequacy of the rotary and sliding mechanisms.

The assembly will be checked for proper alignment to prevent possible jamming.

The torque required to turn the rotary plug will be measured and compared to the rating of the rotary actuator.

6.6 Auger Mechanism

The auger mechanism consists of the auger, housing, and torque motor. The assembly will be operated first manually, then energized under no load to assure interference free operation.

6.7 System Tests

After the successful checkout of the components described above, the system will be assembled into the three major interconnected subsystems:

(1) The warm water storage reservoir

(2) The feces storage container

(3) The commode

The first tests will be confined to an electrical and mechanical checkout to see that all switches, lights, valves, motors and controls operate properly. Most of these tests will be controlled by the programming timer. The sequence and timing of each switch on the timer will be adjusted at this time.

Once the system appears to be in good operating condition, the usage tests will be started. Usages will be at first simulated with the same substitute as used during the concept selection phase. These tests will be conducted over a period of at least three days to observe any incipient effect of local drying and odor propagation.

After satisfactory completion of the simulated tests, actual manned tests will be conducted over a period of one week during which at least fifteen total usages will be completed. A comment sheet will be filled out by the user immediately after each use. These tests will be conducted in a secluded section of our laboratory with complete privacy for the user.

At the completion of the tests, the equipment will be partially disassembled, cleaned, disinfected, reassembled and made ready for shipment.

7.0 INSTRUMENTATION AND EQUIPMENT

The following support equipment is required:

(1) Torque wrench (up to 200 in. lbs.)

(2) Weight scale (1 to 1,000 gms)

(3) Force scale (1 to 100 lbs.)

(4) 28 volts D.C. power supply

(5) 200 volts, 3 phase, 400 cycles generator

(6) Strobe light

(7) Vacuum pump (Welsh Scientific, 5 CFM)

8.0 SCHEDULE

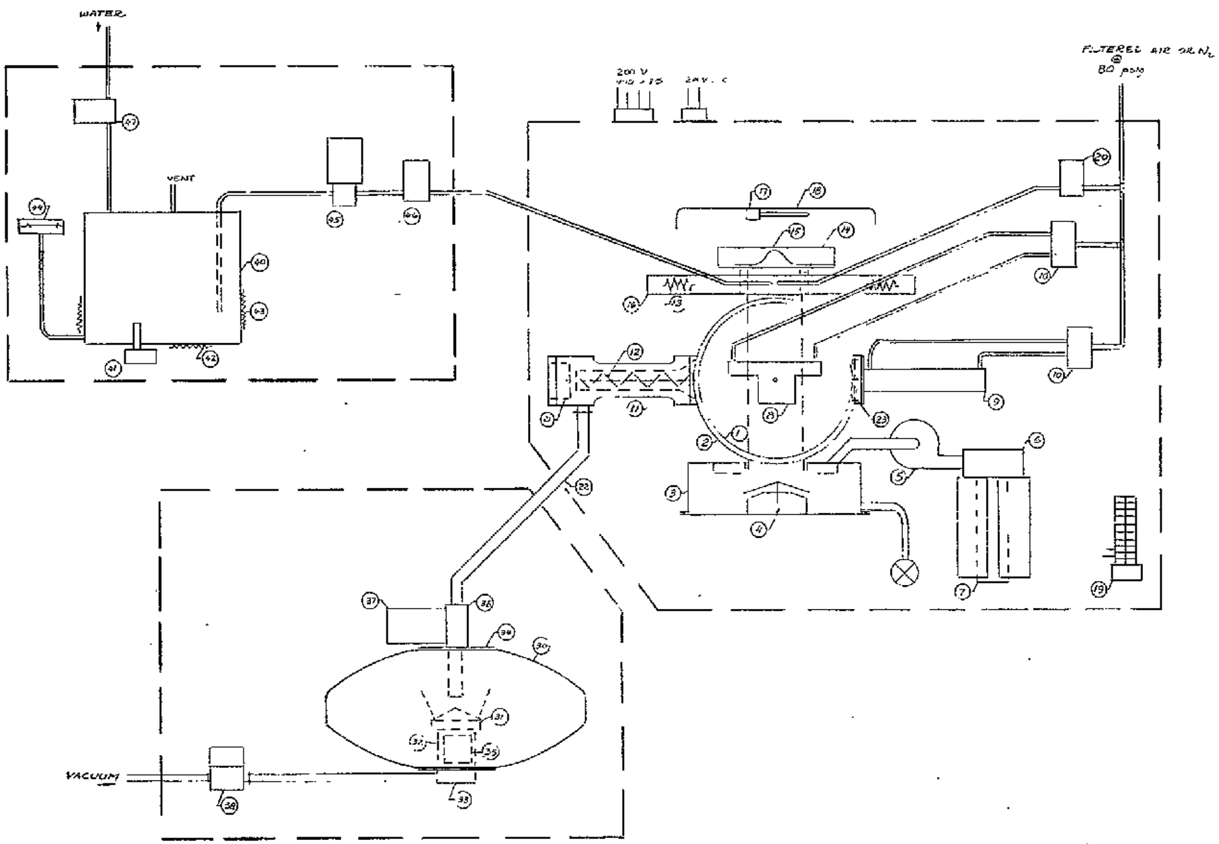
The tests described in paragraphs 6.1 to 6.5 inclusive, will be performed from the beginning of November to approximately December 13. The system test, paragraph 6.7, will begin during the week of December 21 and should end by January 15, 1971.

9.0 DOCUMENTATION

All data will be recorded on a Laboratory Record Book. A test report, including significant laboratory data, will be released at the completion of the program on or before the shipment or the hardware.

FOLDOUT FRAME 1

FOLDOUT FRAME 2



ITEM	IDENTIFICATION	PART NUMBER
47	SOLENOID VALVE	82DX34 SKINNER
46	SOLENOID VALVE	SKINNER
45	GEAR PUMP	09-70-303 MICROPUMP
44	LEVEL SENSOR	LAB UNIT
43	STRIP HEATERS (4)	28 V DC.
42	STRIP HEATER	75 WATTS 110 AC
41	TEMP CONTROL	C47 (UNITED ELECTRIC)
40	WATER TANK	(MADE FROM HARRIS FLOAT)
38	VACUUM VALVE	8210 B34 ASCO
37	VALVE OPERATOR	ST 20 JAMESBURY
36	BALL VALVE	A36TT 3/4 JAMESBURY
35	SLINGER MOTOR	1/20 HP, 2700 FRAME INDUC. - WELCO IND.
34	INLET PLATE	
33	BOTTOM PLATE	SK56197-811
32	MOTOR HOUSING	SK56197-812
31	SLINGER	
30	STORAGE CONTAINER	SK56197-810
23	PISTON	
22	INTERCONNECTION	
21	TORQUE MOTOR	
20	SOLENOID VALVE	B2DX34 SKINNER
19	TIMER	RC5/B-12 (INDUSTRIAL TIMER)
18	COVER	
17	U-V LIGHTS (2)	G4T4/1 (G.E.)
16	HEATER HOUSING	
15	SEAT	
14	ADAPTER	SK56197-814
13	AIR HEATER (2)	SEF 10 CHROMALOX (250 WATTS)
12	AUGER	SK56197-823
11	AUGER HOUSING	SK56197-824
10	4-WAY VALVE (2)	1616A2001 (ROSS)
9	AIR CYLINDER	
8	ROTARY ACTUATOR	1-TIA-4090-A1 (TOM THUMB)
7	AIR FILTERS (3)	PETROSORB MULTIPOR .9 - PALL CORP
6	AIR PLENUM	SK56197-813
5	AIR BLOWER	19A1217 GLOBE
4	TORQUE MOTOR	T 2955 D - INLAND MOTOR CORP
3	PHASE SEPARATOR	SK56197-804
2	PISTON HOUSING	SK56197-821
1	ROTATING PISTON	SK56197-822

G.E. SPACE SYSTEMS KING OF PRUSSIA, PA.

MODIFIED HYDROJOHN SYSTEM SCHEMATIC

NASA CONTRACT NAS 9-9741

SK56197-800

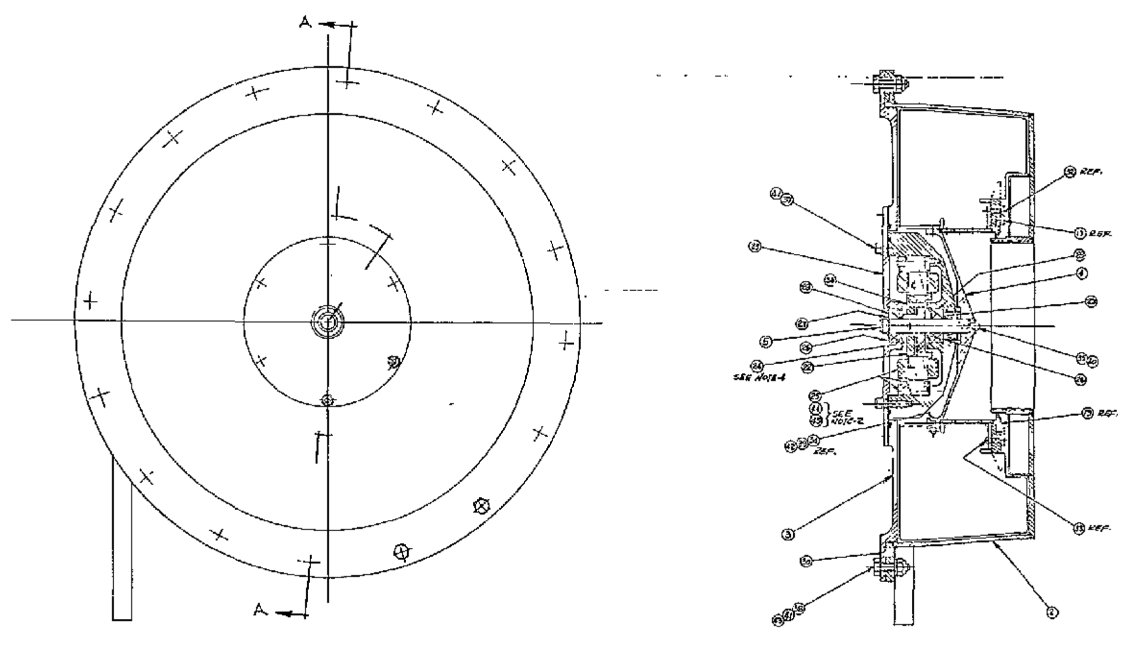
10-15-70

APPENDIX B

PHASE SEPARATOR ASSEMBLY DRAWING

FOLDOUT FRAME 1

FOLDOUT FRAME 2



SECTION A-A

(G1) SEE NOTES 1 THRU 4

(P2) .377±.001 I.D. .46±.01 O.D. WIDTH - SEE NOTE-4

NOTES
1- INTERPRETATION OF DRAWING TERMS AND TOLERANCES PER 11BA1664.
2- SCREWS ITEM No 44 & 45 MAY BE SUPPLIED WITH MOTOR ITEM No 25.
3- ITEMS INDICATED BY "REF." CALLED FOR AT THEIR RESPECTIVE ASSEMBLIES.
4- ITEM No. 24 WIDTH TO BE DETERMINE AT ASSEMBLY LOOSE FIT WITHIN .001 MAX.

QTY	IDENTIFICATION NO.	ITEM NO.	DESCRIPTION	REMARKS
4	MS51959-17	45	SCREW FL HD 82° #4-40NC 2A x 7/16 LG	SEE NOTE 2
4	MS51959-19	44	SCREW FL HD. 82° #4-40NC 2A x 3/4 LG	SEE NOTE 2
16	MS21042 C3	43	NUT, #10-32 NF-2B	
G	NAS1291C04	42	NUT, #4-40NC-2B	
22	MS15795 808	41	WASHER #10	
1	MS15795-806	40	WASHER #6	
G	MS15795 804	39	WASHER #4	
16	AN3C 5A	38	BOLT HEX. HD #10-32NF-3A x 23/32 LG	
G	MS16996-10	37	SCREW CAP HD #10-32NF-3A x 1/2 LG	
4	MS24693C27	36	SCREW FL HD 100° #6-32NC 2A x 7/16 LG	
1	MS51957-27	35	SCREW PAN HD #6 32NC-2A x 5/16 LG	
G	MS24693 C5	34	SCREW FL HD. 100° #4 40NC-2B x 5/16 LG	
G	MS51957-13	33	SCREW PAN HD #4-40NC 2A x 5/16 LG	
G	MS24693 C2	32	SCREW FL HD 82° #4-40NC 2A x 1/4 LG	
1		31	DOWEL PIN 3/32 DIA x 1/4 LG CRES	
1	ARP568.281	30	O RING - C.E. CONVERSE & Co, INC, FAIRFIELD N.J.	
1	1505-5 7/8	29	SEAL U-CUP, HALOGEN INS. & SEAL Co.	
2	SR6S	28	BEARING - BARDEN CORP, DANBURY, CONN.	
1	5100-37	27	RETAINING RING - WALDES KOHINOOR	
2	N5000-87	26	RETAINING RING - WALDES KOHINOOR	
1	T-2965	25	MOTOR - INLAND MOTOR CORP, RADFORD, VA.	
1	SK56197-806 P4	24	SPACER	SEE NOTE 4
1	SK56197-806 P3	23	SUPPORT, BEARING	
1	SK56197-805 P3	22	RETAINER	
1	SK56197-805 P2	21	HUB	
1	SK56197-806 P1	20	SHAFT	
1	SK56197-803 P6	19	SEAL	
6	P5	18	VANE	
1	P4	17	RETAINER	
1	P3	16	CONE	
1	P2	15	PERFORATED CYLINDER	
1	SK56197 803 P1	14	RING	
1	SK56197-807 P2	13	HOUSING, MOTOR	
1	SK56197-807 P1	12	COVER	
1	SK56197-802 P6	11	TUBE	
1	P5	10	PLENUM	
1	P4	9	COLLAR	
1	P3	8	COVER	
1	P2	7	CONTAINER, WALL	
1	SK56197 802 P1	6	FLANGE	
1	SK56197-[illegible]	5	SHAFT ASSEMBLY	
1	SK56197-[illegible]	4	IMPELLER ASSEMBLY	
1	SK56197-[illegible]	3	HOUSING ASSEMBLY	
1	SK56197-[illegible]	2	CONTAINER ASSEMBLY	
	SK56197-[illegible]	1	PHASE SEPARATOR ASSY	

LIST OF MATERIAL

GENERAL ELECTRIC

S.S.D.

PHASE SEPARATOR ASSEMBLY

E 25391 SK56197-804

NOT REPRODUCIBLE.

FINAL REPORT

CONCEPT SELECTION AND EVALUATION

FOR

MODIFIED HYDRO JOHN

CONTRACT NUMBER NAS 9-9741

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

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1.0 SUMMARY

This report covers the test and evaluation of three proposed concepts for the Modified Hydro John system. All three concepts are based on positive displacement of the fecal material from the collection chamber to a storage and treatment container.

The collection is based on the Hydro John design except that the fecal solid material is separated from the anal flush water.

The storage and treatment is done by vacuum drying as in previously tested Dry John systems. The Dry John uses a high speed rotating plate (slinger) to spread the material against the surrounding walls of the storage container where the vacuum drying takes place.

Concept #1 uses a rectangular piston and an auger to displace the fecal material into the storage container.

Concept #2 is similar to Concept #1 except for the addition of a wiper to minimize the accumulation of solids on the face of the piston.

Concept #3 uses a rotating piston used to move the collection chamber from vertical, during collection, to horizontal for direct displacement into the storage container.

The tests were performed using full scale models of the proposed concepts and were limited to the performance of the slinger action for the storage container and the piston/auger action for the basic commode. The test results and the analysis show that a modified and simplified Concept #2 using a moving plate instead of the piston may be the best selection. The modification eliminates the only significant objection applicable to Concept #2.

#2

2.0 INTRODUCTION

During the past years, the General Electric Company has developed two basic approaches to the design of feces management systems for space application.

In one approach, the Dry John, the feces and toilet paper are collected, treated, and stored immediately below the toilet seat area.

In the other approach, the Hydro John, the toilet paper is replaced by a warm water and flush and air drying. The water is then mixed with the feces and pumped out to the spacecraft water recovery system.

The purpose of the present Modified Hydro John program is to make specific changes to the basic Hydro John design to minimize the amount of fecal solids in the flush water delivered to the spacecraft water recovery system. The bulk of the fecal material is to be pumped to a separate sanitary storage subsystem without mixing with the anal flush water. The flush water will be further used to partially rinse the container then pumped to a water recovery system through a phase separator.

The basic concept to accomplish the above function is shown in Figure 1.

The feces are conveyed into the unit by an air flow for zero "g" operation (with the piston retracted). A perforated plate at the bottom of the chamber retains the feces while permitting the air to pass thru. The feces are then moved by the piston and forced into an auger which conveys the wastes into the solids processing unit. The piston, when in the extended position, opens a second thru chamber which also exposes the perforated plate. The flush cycle is begun and the water is conveyed by the air flow thru the perforated plate and into a liquid gas separator.

The user and the equipment are thus washed clean. The liquid and air are separated in a centrifuge device with the air returned to a cabin by a blower-filter unit and the flush water is pumped to the water recovery unit. The user and equipment are dried by the air flow and the system is ready for use again. This design is identified as Concept #1.

Concept #1 is limited by the size of the auger. Ideally, the auger should have an inlet opening as large as the face of the displacement piston to avoid trapping the feces into a dead space at the end of the stroke. This problem is minimized in Concept #2, shown in Figure 2. The auger is located at the top corner of the chamber and a wiper is added to move the waste material into the auger.

In both concepts, the feces are pumped through a valve into a storage container. A rotating element (slinger) immediately below the container inlet shreds and accelerates the fecal material to form a thin layer against the container wall. The layer is then rapidly vacuum dried to inactivate the fecal bacteria by connecting the container interior to space vacuum.

In Concept #3, Figure 3, the sliding rectangular piston is replaced by a rotating piston. The system works very much the same as the other two except that the collection chamber, i.e., the vertical cylindrical portion below the seat, is rotated 90° in line with a horizontal piston which displaces the feces directly into the storage container.

The slinger tines are fitted with a cutting edge which removes the feces from the piston. The piston is then retracted and the chamber is rotated back to the vertical position for the flush cycle.

The seal between the normally evacuated container and the rest of the system is obtained by means of "O" rings at the edge of the collection chamber in the rotating plug, see Figure 3.

Working models of the three concepts were fabricated using transparent plexiglas wherever possible. The models are illustrated in Figures 4, 5, and 6. The model shown in Figure 4 uses the same storage container that is shown in Figure 5.

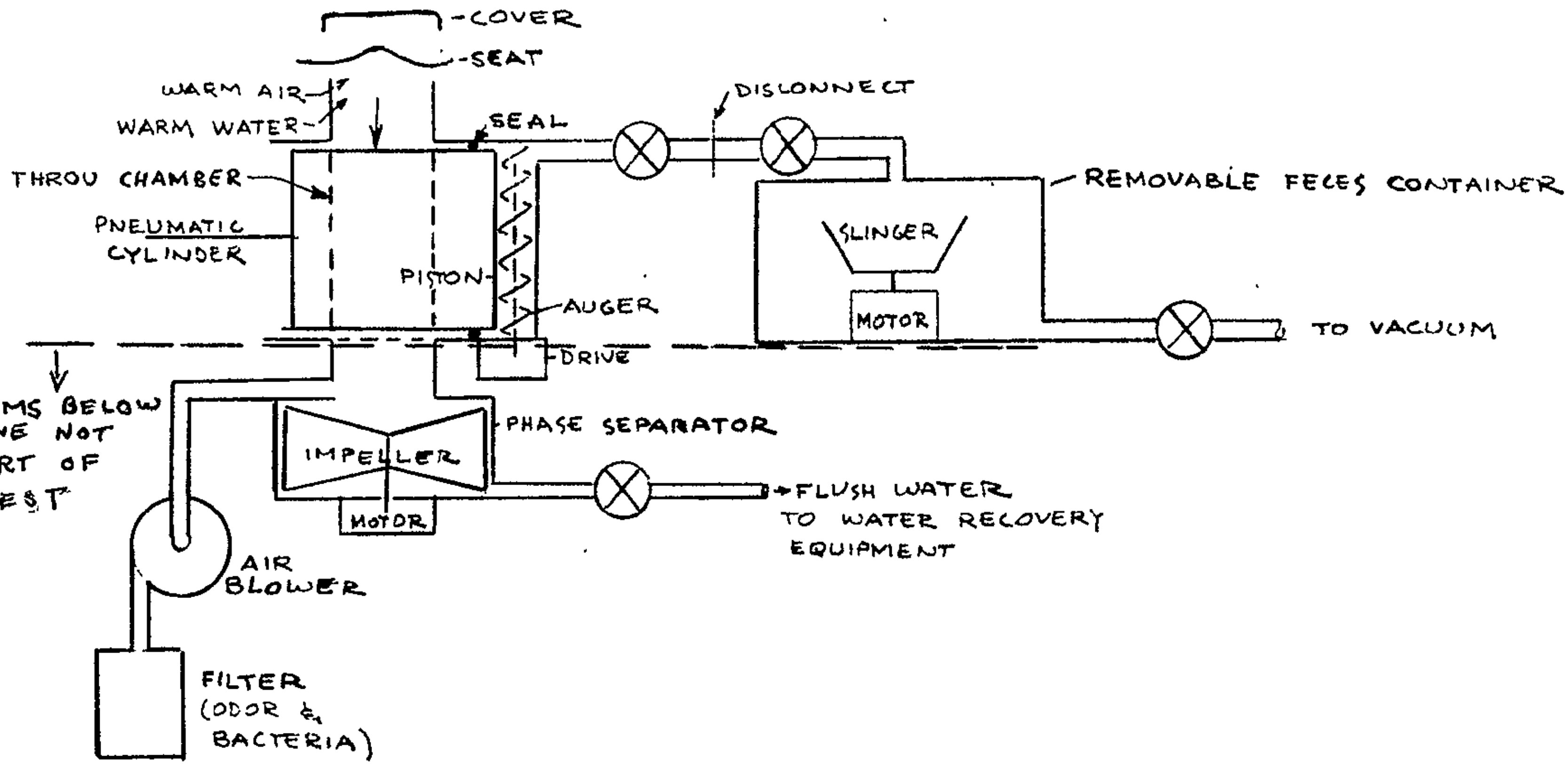


FIGURE 1. SCHEMATIC DRAWING OF CONCEPT #1

JKM 6-10-70

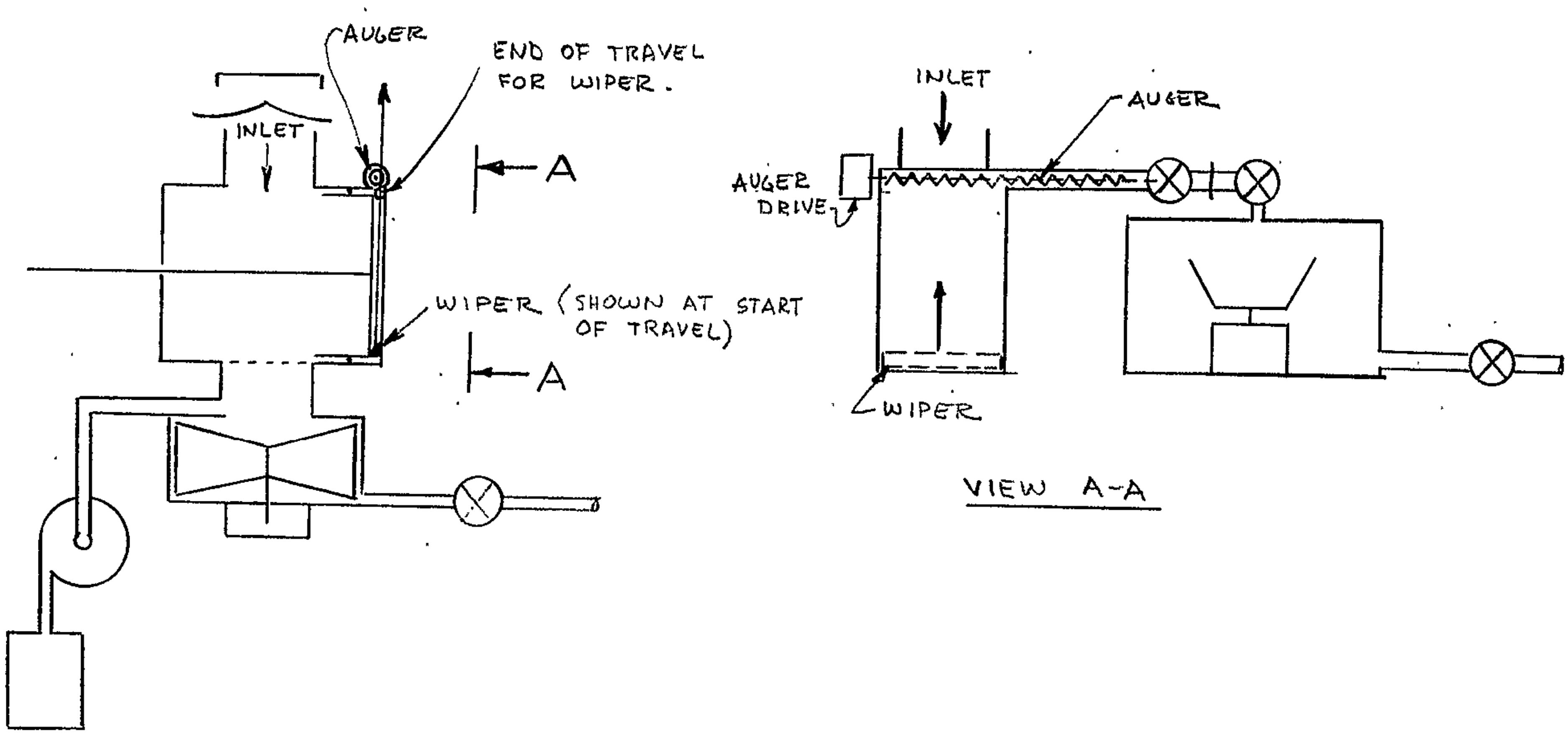


FIGURE 2. SCHEMATIC DRAWING OF CONCEPT #2 - (SAME AS #1 EXCEPT AS SHOWN)

JKM - 6-10-70

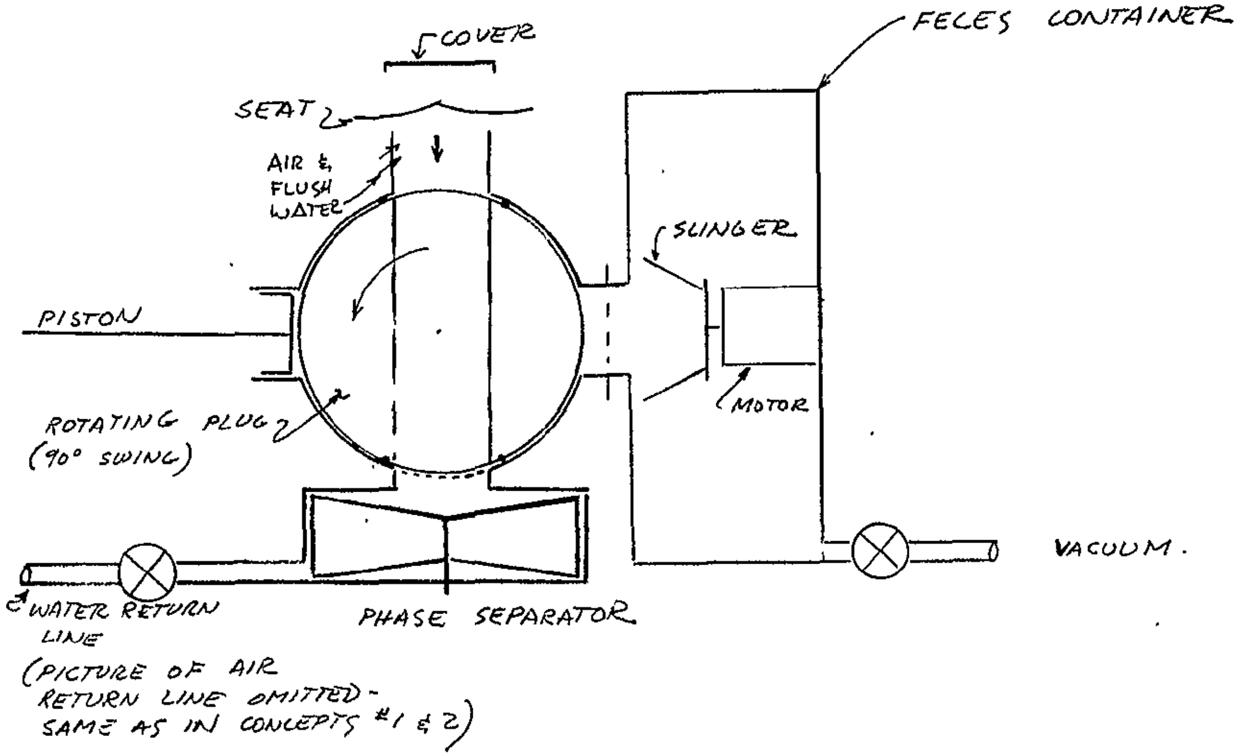


FIGURE 3 - SCHEMATIC DRAWING OF CONCEPT #3.

JKM 6-10-70

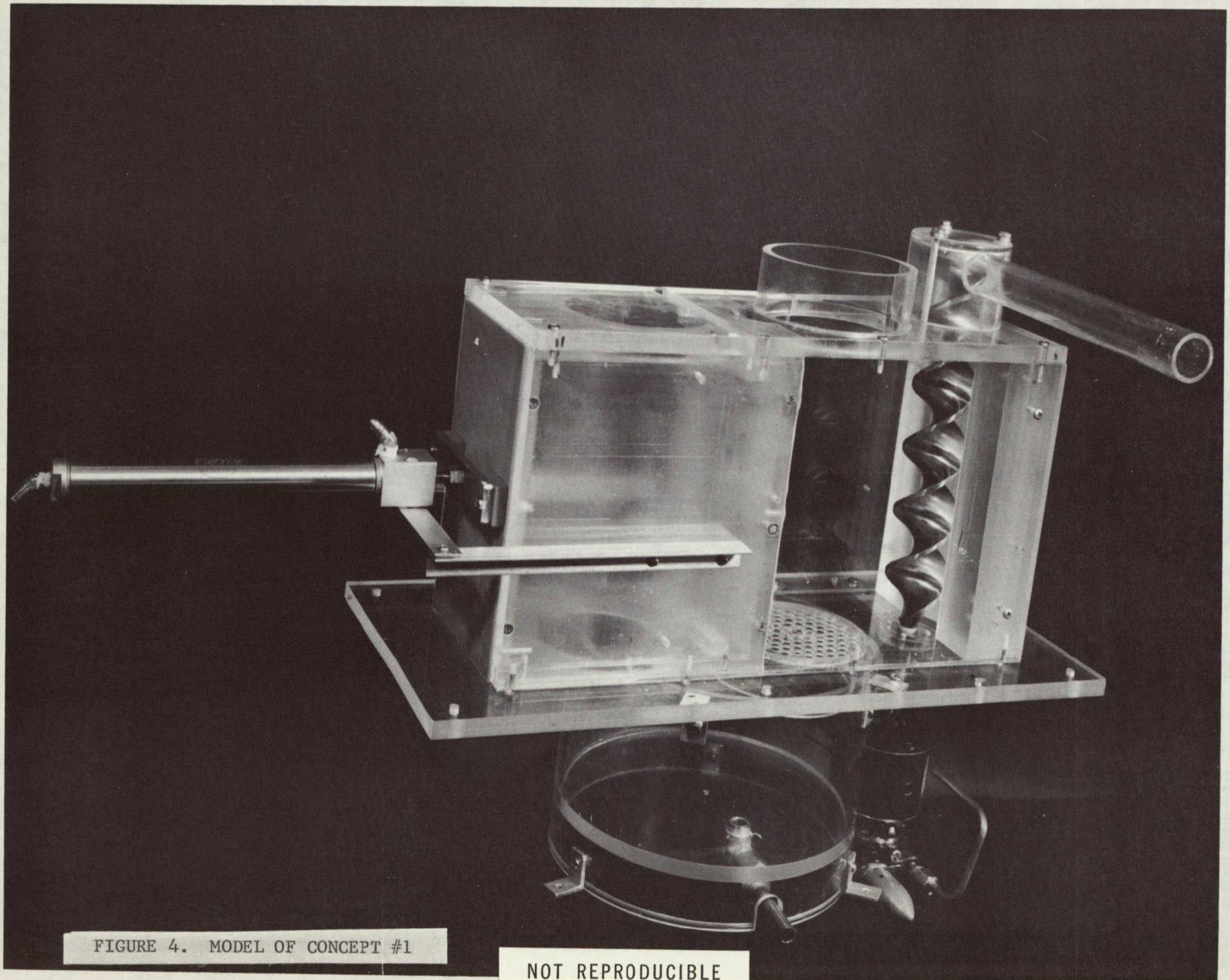


FIGURE 4. MODEL OF CONCEPT #1

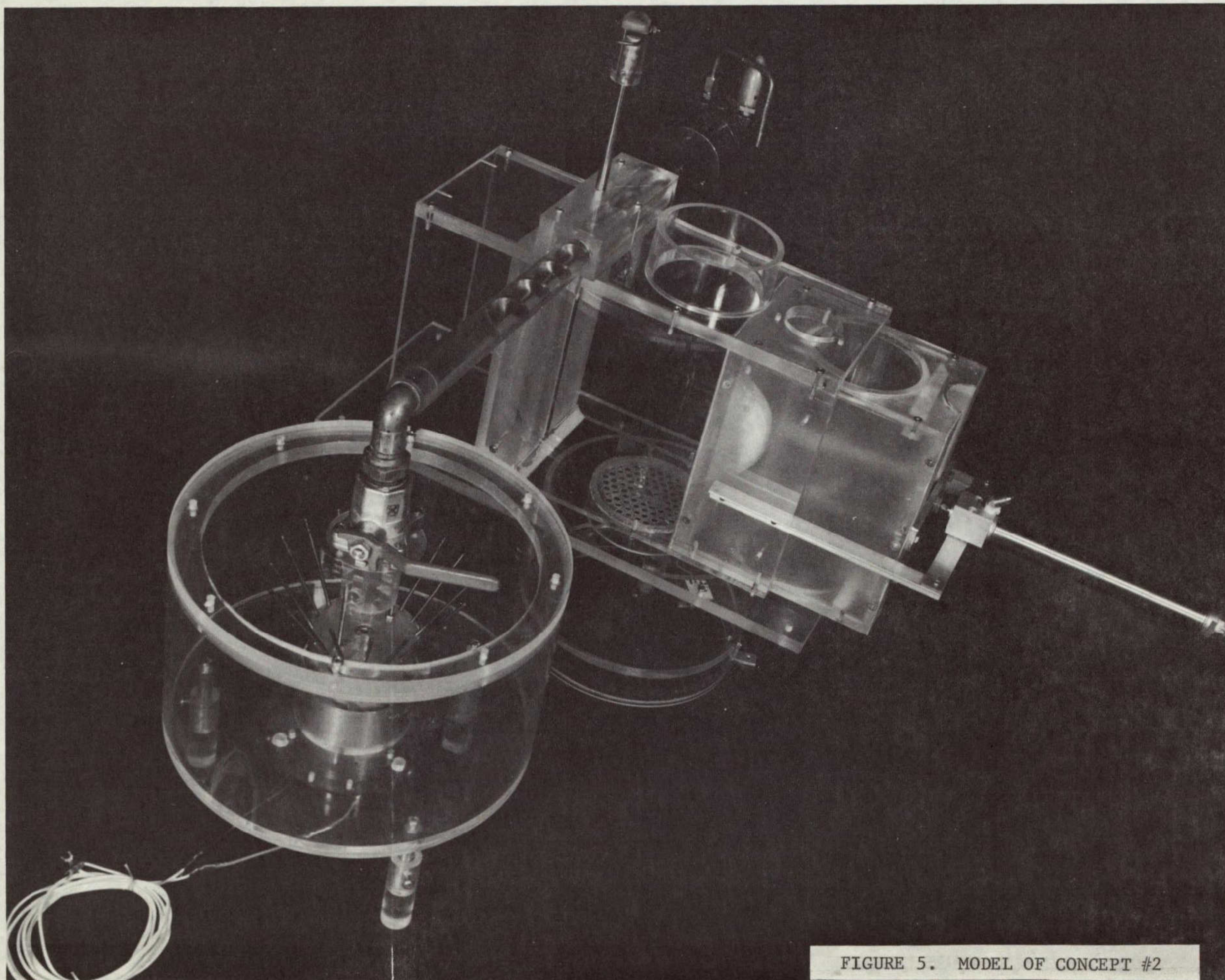


FIGURE 5. MODEL OF CONCEPT #2

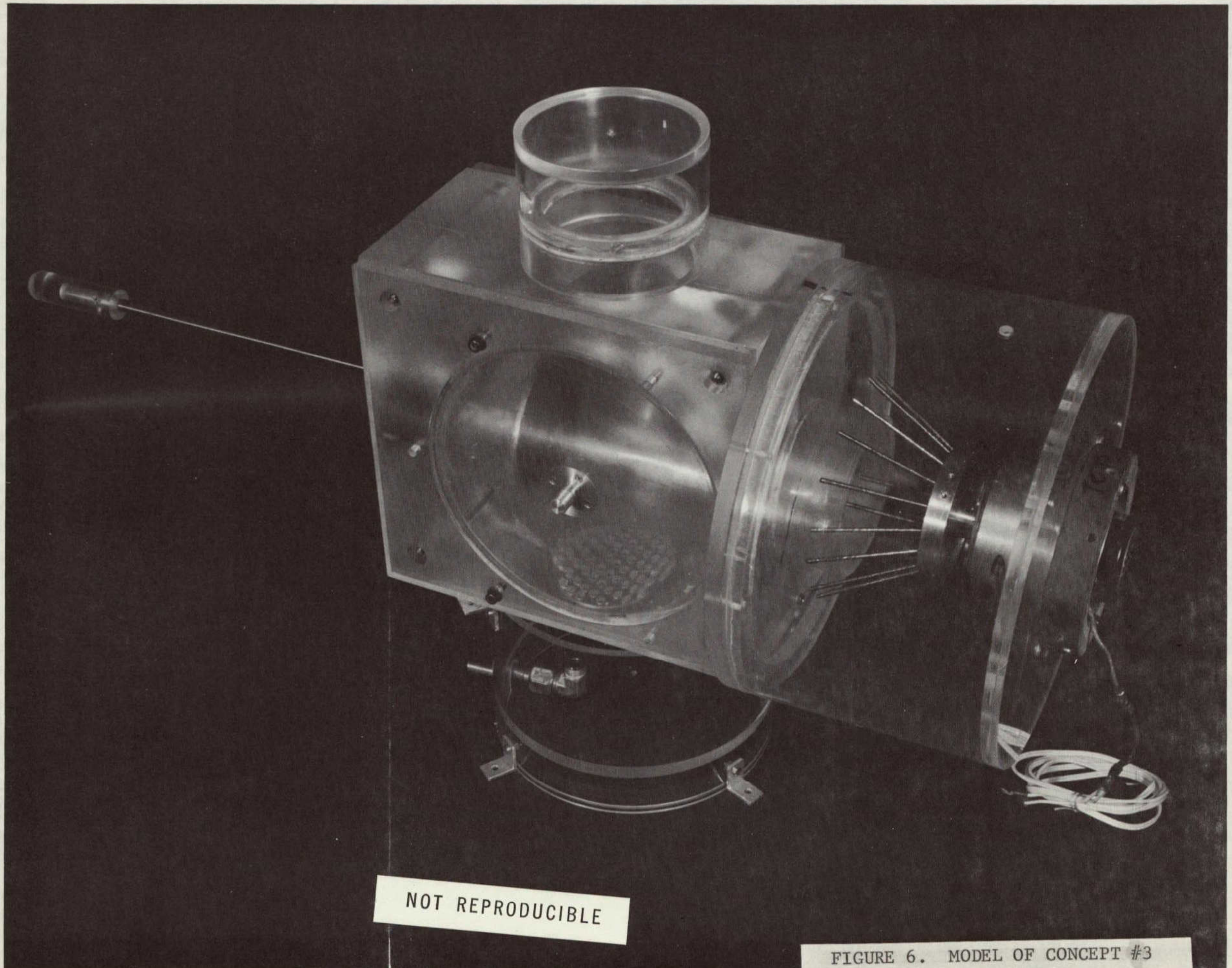


FIGURE 6. MODEL OF CONCEPT #3

3.0 TEST DESCRIPTIONS

The laboratory tests were conducted in two phases. During the first phase, the testing was concentrated on the performance of the slinger under the possible different operating conditions for the Modified Hydro John. During the second phase, the tests were concentrated on the operation of the complete models. This sequence was adapted namely for schedule convenience since the storage container and slinger assembly could be easily fabricated using hardware available from previous similar tests.

3.1 Slinger Tests

The feces from the Modified Hydro John will be processed by vacuum drying in a storage container in the same manner as in the typical Dry John design. The drying takes place on the walls of the container where the feces has been positioned by the rotating slinger.

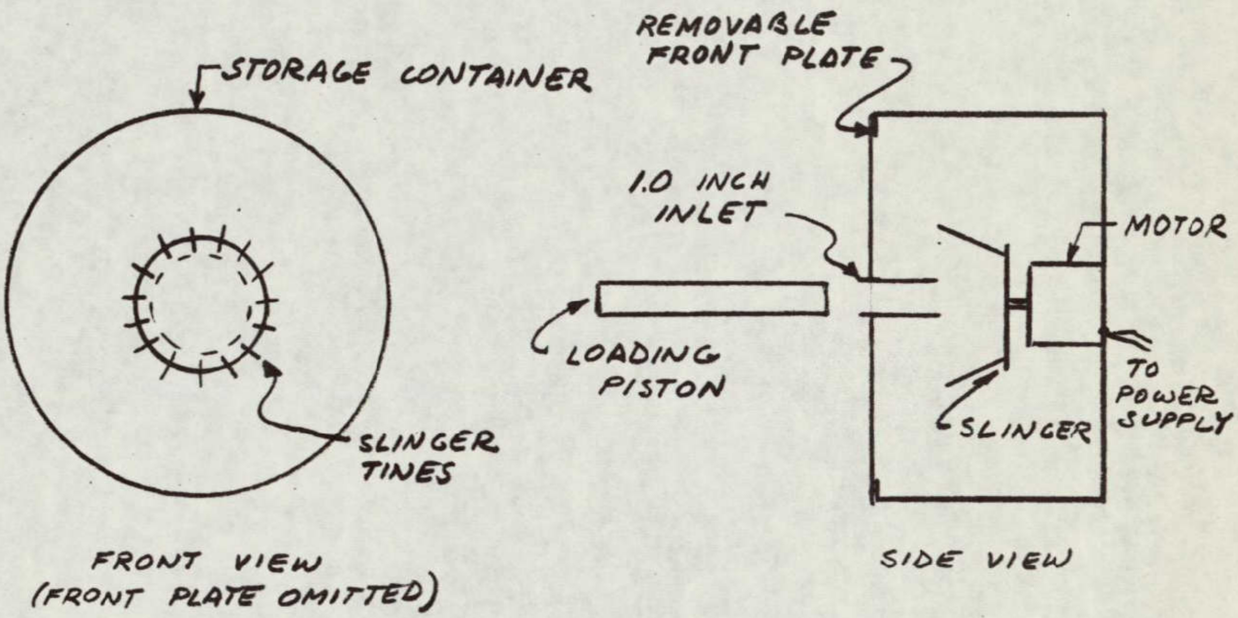
Although there is no planned change in the basic slinger-container design, the additional tests were made necessary by the method by which the feces are introduced in the container. In the typical Dry John design, the stool first separates from the anus then it moves by free fall (in one "g") or air flow (in zero "g") into the slinger. In the Modified Hydro John, the stool remains attached to the inlet tube facing the slinger. The separation must be done by the slinger. Furthermore, the inlet tube may be horizontal rather than vertical.

There were two types of slinger tests performed using the same basic container-slinger arrangement. One type used a 1" I.D. inlet

tube applicable to Concepts #1 and #2. The other type used a 4" I.D. inlet tube simulating the conditions of Concept #3. The container was made from a 12" diameter plexiglas tube. The slinger and motor was from previous Dry John tests.

3.1.1 Tests With One Inch I.D. Inlet Tube

The test set-up was approximately as shown below.



The container was set-up with the inlet tube in a horizontal position to simulate the worse case configuration.

The slinger speed was calibrated as a function of the motor voltage in the range from 800 to 2,600 RPM. The feces was simulated by using a 3:1 mixture of Jiffy peanut butter and Ken-L-Ration Burger. The Ken-L-Ration Burger had been soaked in water (2 parts Burger, 1 part water). All ratios are by weight. It was unamiously agreed that the above recipe duly and truly was an excellent simulation of human feces in texture, consistency, color and when properly rolled, even shape.

Odor simulation was not required since no part of this process is ever exposed to ambient conditions.

The initial tests immediately indicated that gravity would cause the material to bend or break and contact the slinger tines at six o'clock .

Since the stool contacts the slinger tines at almost zero velocity, the stool would tend to pass through the tines in large chunks with consequent poor distribution. This condition was remedied by adding two inner tines spaced as close to the outside diameter of the inlet tube as possible. Also, to avoid the sliding of the solids collected on the wall, four retaining strips were added at the critical points on the internal wall of the container. It is to be noted that the plexiglas wall is extremely smooth, a condition which would not exist in the actual hardware. The additional tines and the retainers are shown in Figure 7.

The subsequent tests, conducted with and without the retainers, showed that the addition of the inner tines caused an ideal uniform distribution of the waste material around the container wall while the retaining strips prevented the material from sliding. The improvement in distribution was caused by the fact that the inner tines shear the extruding material at random, in relatively small increments and throw it at high speed against the outer tines. Here the loose material is again shredded and thrown against the container wall.

Similar tests performed with the container and slinger in a horizontal position showed that the distribution, although satisfactory, was not as good namely because the extruded material tends to touch the center of the slinger plate first then shear away mostly in one large chunk. The center of the slinger is left with an accumulation of solids approximately 1/16 inch thick.

Conclusions and observation from this phase of tests:

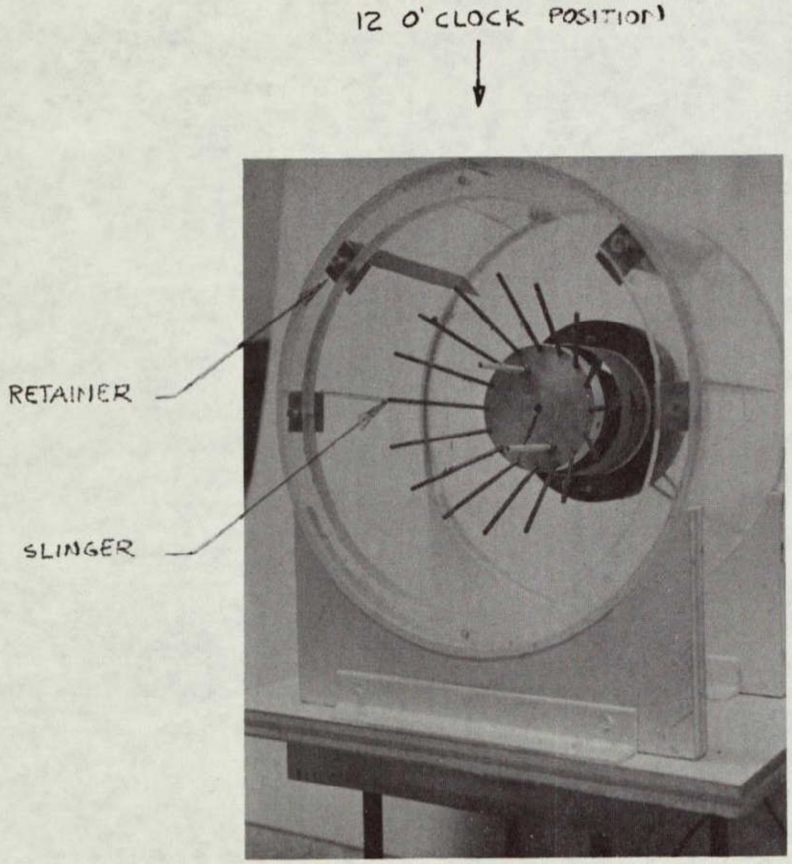
(a) The change in "delivery" of the solid stool should present no major problem.

(b) Two additional tines will greatly improve the distribution of fecal material on the wall. This uniformity of distribution is important for two reasons: it minimizes the vacuum dry time; it makes possible better utilization of the container volume.

(c) The container can be used in any position; however, the internal surface should not be smooth. Also, retainers would be required for a vertical set-up.

(d) The retainers, if used, should be aligned with the tangent of the tines circle of rotation to avoid shadowing. This effect is shown in Figure 8. In this case, the rotation is counter-clockwise. Note the accumulation on one side of the retainer and clean segments on the other.

(e) A horizontal slinger plate is more prone to accumulation of solids. This should not be a problem because once the accumulation reaches any significant thickness, it would eventually shear off.



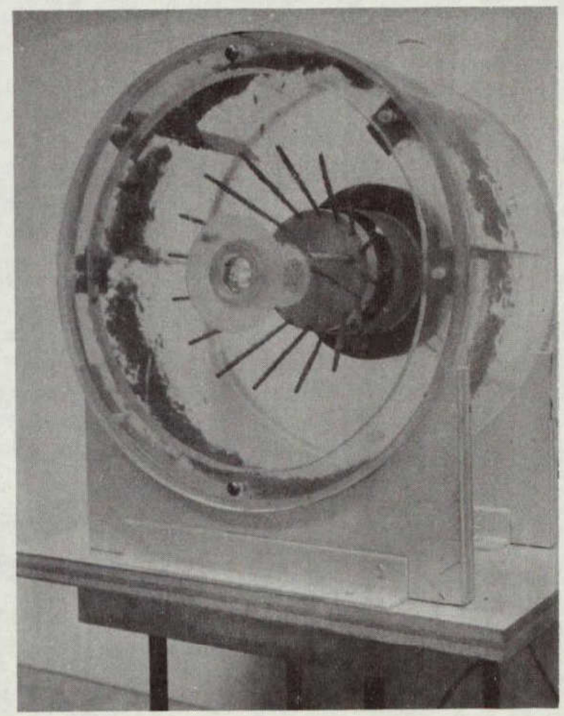


FIGURE 7

FIGURE 8

(f) The power required to turn the slinger is minimal, less than 10 watts. There is no sudden applied load of the magnitude possible in the regular Dry John. Here the size of the "stool" cannot exceed the diameter of the inlet tube by the distance between the plate and the inlet tube.

3.1.2 <u>Tests With Four Inch I.D. Tube</u>

The test set-up was similar to that used for the one inch I.D. inlet with the exception that the front plate was exchanged with one with a four inch opening. The tests were performed with the container in a vertical position only, because this is the only configuration needed for Concept #3.

A larger slinger plate had to be fabricated to allow for the larger inlet tube. A stainless steel wire was attached across two tines as shown in Figure 9.

The first tests showed that the wire was effective in removing the material from the moving piston. However, the slinger did slow down and completely stalled when the material was introduced at a fast rate (approximately one second/stroke). The possibilities of stalling were eliminated when the slinger was fitted with a 1/3 HP motor which was obviously more than adequate. Initially, the motor was operated at 1,500 RPM. Later the speed was increased to 2,200 RPM which was the maximum possible. Also, tests were performed where the slinger was changed into a basket by adding a screen with 1/4 inch openings, see Figure 10.

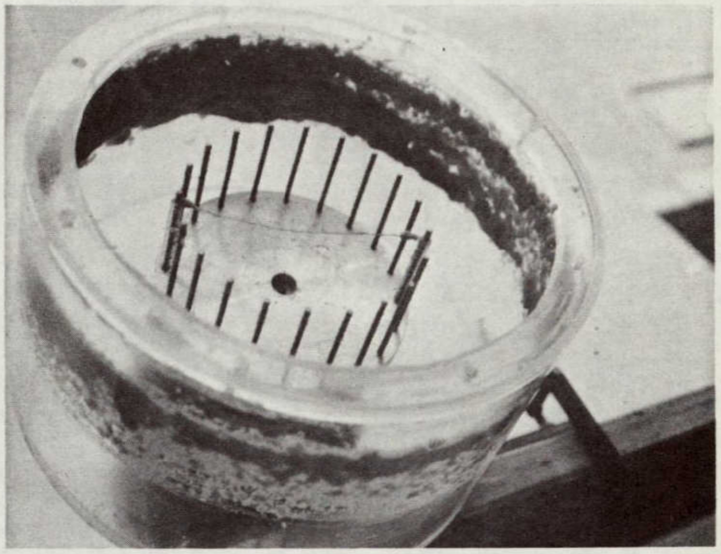


FIGURE 9

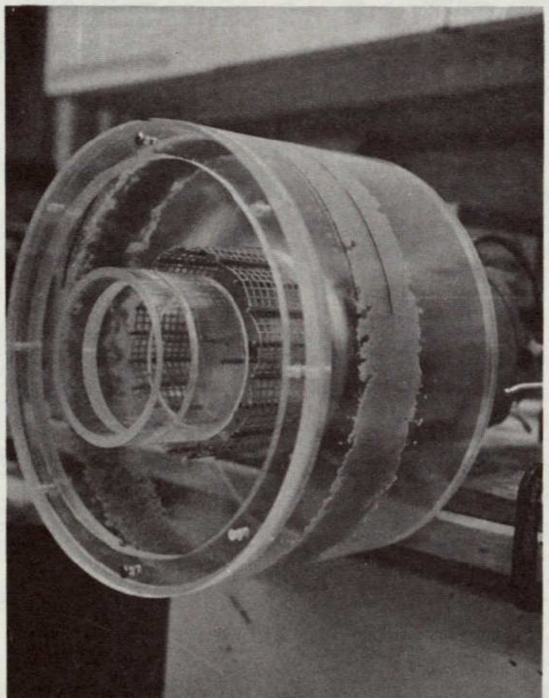
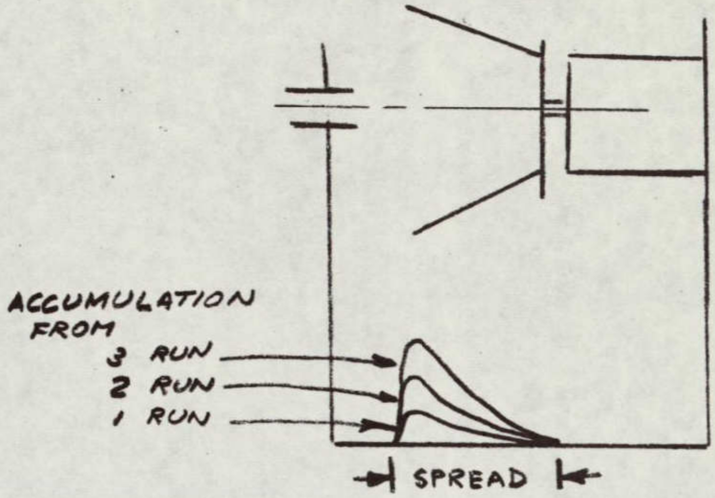


FIGURE 10

Conclusions and observations from this phase of tests:

(a) The slinger from Concept #3 needs a more powerful motor.

(b) If the material is moved into the slinger slowly, an excellent uniform distribution is achieved. However, the width of the band is narrow, see below, and undesirable for an efficient storage container design.



(c) The addition of the basket-type slinger does not increase the spread on the walls of the storage container.

(d) The spread is improved with the basket by first sliding the material into the non-rotating basket and then turning the motor on at full power.

(e) The same effect can be achieved by sliding the material with one fast stroke into the rotating basket.

(f) There is no noticeable difference between slinger configurations (tines or basket) provided that the material is introduced at high speed.

(g) The uniformity of distribution decreases as the speed of the loading piston increases.

(h) The piston face is cleaned by the cutting wire. The amount of residual depends on the clearance between the wire and the piston.

(i) The configuration of the wiping wire does not affect the distribution or spread on the container walls. The wire was replaced by metal strips, or sections of strips with no noticeable difference. Therefore, the wire is best because it offers the minimum surface area.

(j) The feces container for Concept #3 would be relatively larger in diameter for the same storage volume because of the increased slinger diameter.

3.2 System Tests

The system tests were performed using the plexiglas models shown in Figures 4, 5, and 6. The auger was turned by means of an air motor with gear reduction. Air cylinders were used for the linear travel of the piston except for Concept #3 where the piston was operated by hand. The simulated feces was made using the same mixture used for the slinger tests except that it was varied in hardness by controlling the amount of water. The odor tests were performed by using plain "Tabby" cat food. In any case, approximately 150 gms of material per test were used. The material was shaped into the form of a stool. See Figure 11 for a typical loading of the chamber.

3.2.1 Tests on Concept #1

The simulated phase separator was calibrated for 750 and 1250cc's and connected to a sink. The anal spray water was simulated with a shower head fitted inside a Plexiglas cap. The cap was fitted tightly over the inlet opening. See Figure 11.

The tests were performed in the general following sequence:

(a) Removed inlet cap.

(b) Dropped simulated stool from a point where the anus would be located.

(c) Energized the air motor.

(d) Energized the air cylinder operating the piston.

(e) Placed cap back in place and opened water spray.

(f) Stopped water when the 1250 cc's mark was reached.

(g) Retracted piston.

The slinger portion of this test was omitted.

The anal spray was simulated by allowing water to drip from the inlet cap. The simulated phase separator was calibrated for 750 and 1250 cc's which are the levels used on the standard Hydro John system.

The slinger operation was omitted during this phase of tests.

As previously noted, the configuration for the feces container slinger, inlet tube, valve and line connection to the auger is the same for either Concept #1 and Concept #2. Because of hardware availability, the complete Concept #2 was tested before Concept #1. This obviated further tests on the slinger when Concept #1 was tested.

Observations from the tests:

(a) The simulated feces tended to flatten out and fill the dead space between the face of the moving piston and the stationary portion of the end of the chamber where the auger is mounted. Even by increasing the line pressure

to 80 psi, corresponding to a force of 72 pounds, there remained a gap of approximately 0.10 inch partially packed with simulated feces. See Figure 12.

(b) When pulling the piston back, a good portion of the dead space material came back with the moving piston. See Figure 13. Addition of a water spray did not improve the conditions.

(c) The pressure exerted by the piston on the simulated stool caused the material to penetrate through all the most minute adjacent joints of the plexiglas models.

(d) The holes at the bottom of the chamber get considerably contaminated by the dropping stool; however, they are washed clean by the anal flush water.

(e) The torque required to pump the material through the auger and the tube is approximately 20 in-lb. This was measured by removing the air motor and using a torque wrench with a near uniform motion (one to two seconds per turn).

(f) The auger is not self-cleaning. However, when the auger is turned from vertical to horizontal, the auger tends to move most of the material into the tube connecting to the slinger, thus becoming self-cleaning.

(g) There is a slow time delay in the pumping action. The simulated feces keep extruding from the tube for a while after the auger is stopped. It looks very much like paste (caulking compound, for example) coming out of a tube after the squeeze has been stopped. The paste keeps

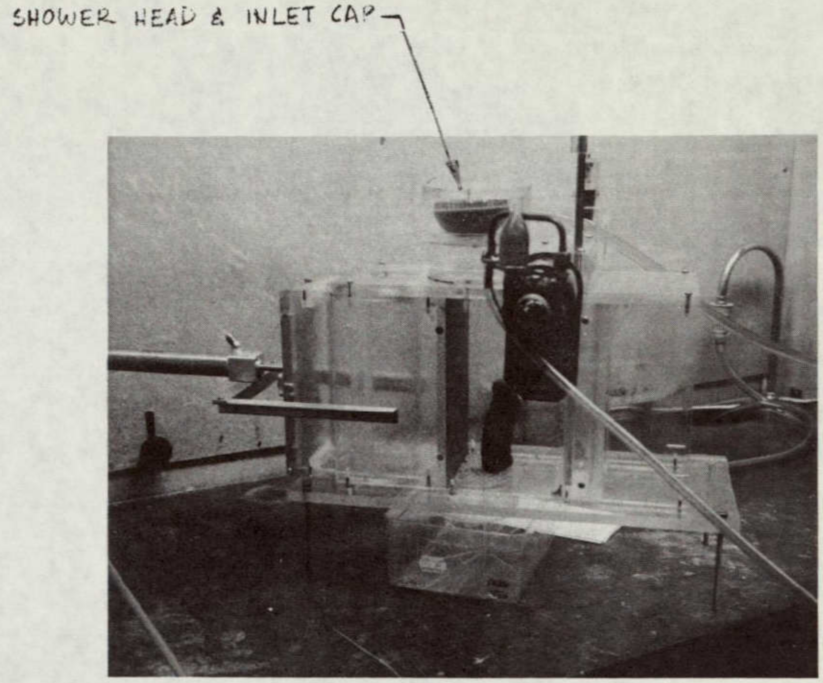


FIGURE 11

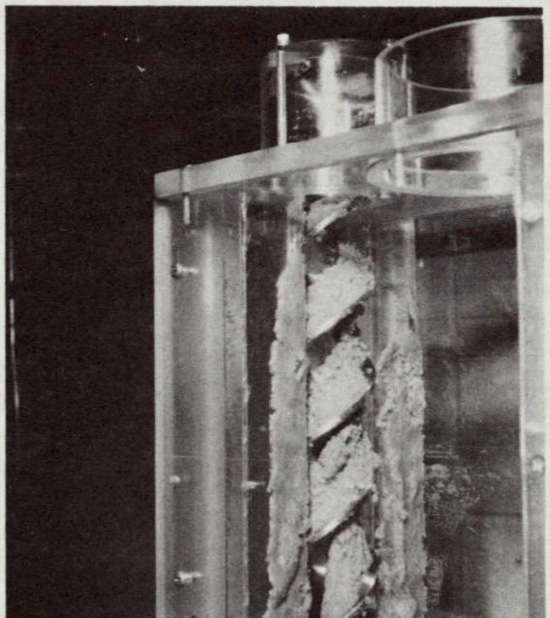


FIGURE 12

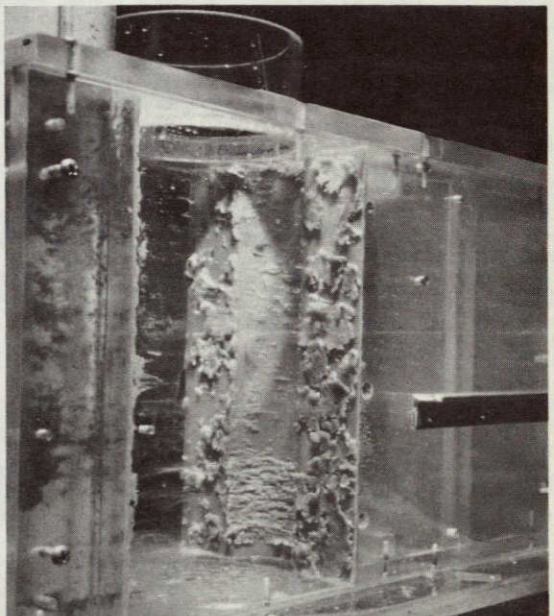


FIGURE 13

coming and it can't be stopped until all the internal pressure has been equalized to ambient.

3.2.2 Tests on Concept #2

The tests and procedures for Concept #2 are basically the same as those used for Concept #1 except that at the end of the piston stroke, the feces are moved into the auger by the wiper action.

The general observations and conclusions from these tests can be summarized as follows:

(a) The width of the wiper should approximate the average diameter of the stool to minimize the flattening of the stool caused by the displacement piston. Flattening caused contamination of surfaces plus increased force by the displacement piston.

(b) The force required to move the piston and produce a partial squeeze equal to the width of the wiper (1/2 inch) was 35-40 pounds.

(c) The maximum force required to pull the wiper up on dry surfaces was 32 pounds. The friction is much reduced if the surfaces are wet by the anal spray water.

(d) The torque required to turn the auger and pump the simulated feces through the tube and into the slinger was approximately 8 in-lbs.

(e) The penetration of solids into the joints of the model is not as severe as in Concept #1 and is limited to the area around the auger.

(f) The attempts to use a plug valve made with tapered rubber stopper (designed for easy separation of the feces container) had to be quickly abandoned. It became evident that the pressure created by the auger caused every surface between the auger and the slinger to be permeated by the simulated feces. A considerable amount of solids would be left in the interface between the plug and the mating surface regardless of the pressure applied to reseat the plug.

(g) A ball valve seems to work satisfactorily as a shut-off valve between the container and the auger.

(h) The wiper did not work too well in cleaning the face of the piston when the piston was dry. This was probably aggravated by the uneveness of the rubber pad bonded to the face of the piston. Wet material would slide up easily leaving little residue on the wall. Actually, the "dry" simulated feces slips between the edge of the wiper and the relatively soft rubber face of the piston forming innumerable little curls which remain attached to the piston. This condition did not occur in the back of the wiper where the metal of the wiper is in direct contact with the plexiglas plate. Conclusion: Keep the face of the piston hard and smooth and perhaps a soft edge on the wiper only.

(i) It appears that a piston without the additional chamber for anal flush would be better because, barring other complications,

it would allow the face of the piston to get wet during the anal flush cycle. This would allow a smoother wiping and pumping operation.

(j) The auger seems to be self-wiping to a degree, depending on the consistency of the material pumped through. See Figures 14 and 15.

(k) The cleanliness of the holes at the bottom of the collection chamber will depend mostly on the pattern of the water dripping from the top. When the water drips rather uniformly, then the holes will clean. If most of the water were to congregate into a stream before hitting the bottom, then most of the dirty holes will not clean.

(l) The dripping water is not an effective wash for the face of the piston. Only the wiping action or extended direct water spray are effective.

(m) Piston tends to slam and jolt the whole system if actuated too fast.

(n) When a better, tighter cap was used to simulate the anal flush, the air compression caused by the piston travel caused the cap to blow off the unit. This means that the displacement of the piston must be subordinated to the air flow to avoid ambient contamination.

(o) Odor is no problem provided that there is an inward air flow. Tests were run by using the "Tabby" cat food which has a rather strong odor. An inward air flow was obtained by connecting the simulated phase separator to a small

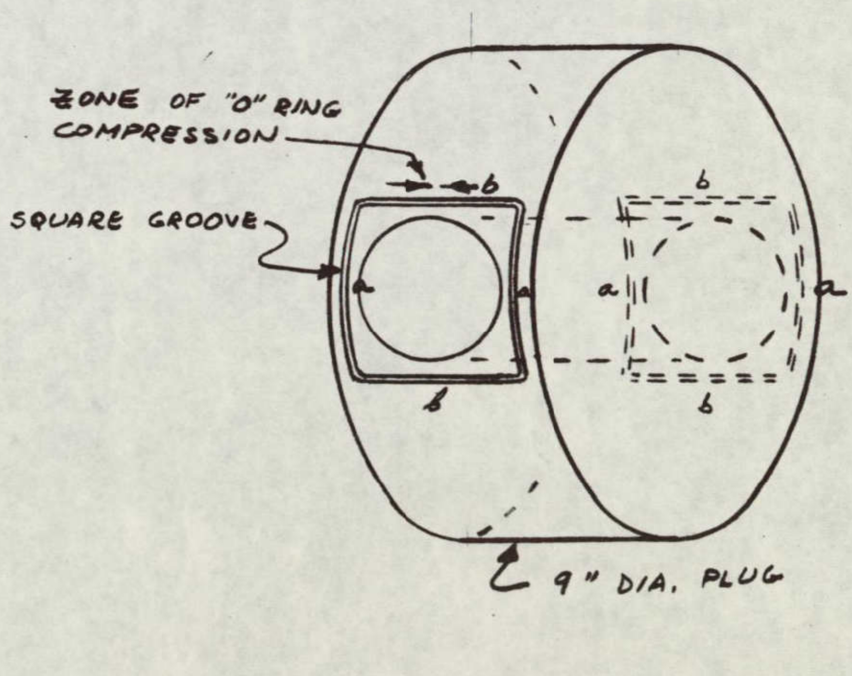
vacuum pump. The average air velocity created at the inlet of the collection chamber was measured at 50 feet/minute. This corresponds to an air flow of about 4.5 CFM which is much less than the normal 10 CFM normally prescribed for the system.

3.2.3 Tests on Concept #3

The initial tests performed on the model for Concept #3 were aimed at determing the amount of torque required to turn the 9.0 inch plug which rotates the collection chamber from the vertical to the horizontal position.

The tests were performed by turning the plug with a torque wrench while recording the time for the 90° swing with a stop watch.

After nine cycles, one of the two "O" rings on the plug came off the groove. This failure was probably due to the shape of the "O" ring groove used to make possible the fast, in-house fabrication .



Apparently, the "O" rings tend to stretch along the curved portion of the groove (a) while the plug travels from one position to the other. The stretch causes the "O" ring to compress lengthwise within the straight portion of the groove (b). The results are shown in Figure 16. Upon disassembly, both "O" rings were badly damaged. New "O" rings were replaced and bonded in the groove with Silicone rubber cement.

The torque recorded with the new "O" rings are plotted in Figure 17.

After the initial torque measurements, the tests were concentrated on the performance of the model with the same simulated feces which had been used for Concepts #1 and #2.

The test sequence was as follows:

(a) Drop simulated stool in chamber.

(b) Rotate piston clockwise until it locked in place.

(c) Turn slinger on.

(d) Push piston in through plug bore and into storage container inlet.

(e) Retract piston.

(f) Rotate piston counter-clockwise.

(g) Use anal flush.

This sequence was repeated several times and with feces of different water content (hard and soft).

The general observations and conclusions are:

(a) There is no problem with the general alignment and piston operation.

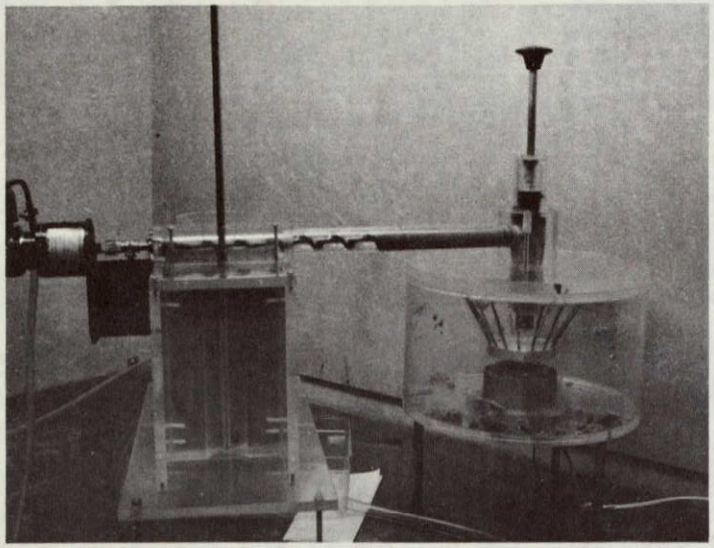


FIGURE 14

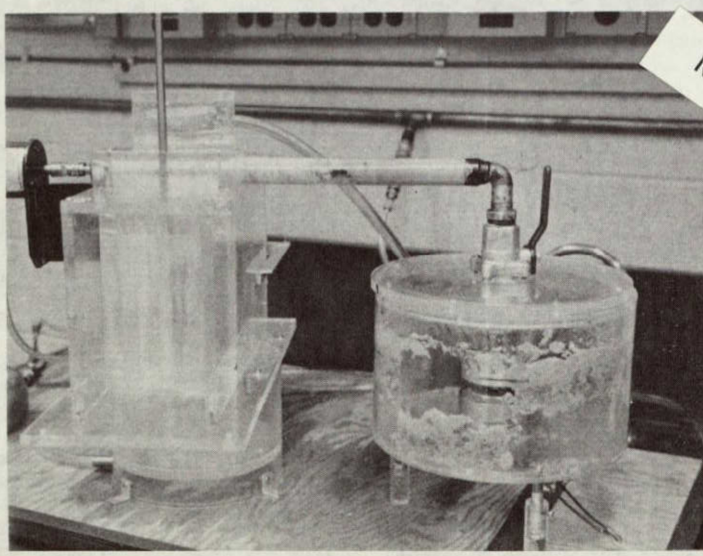


FIGURE 15

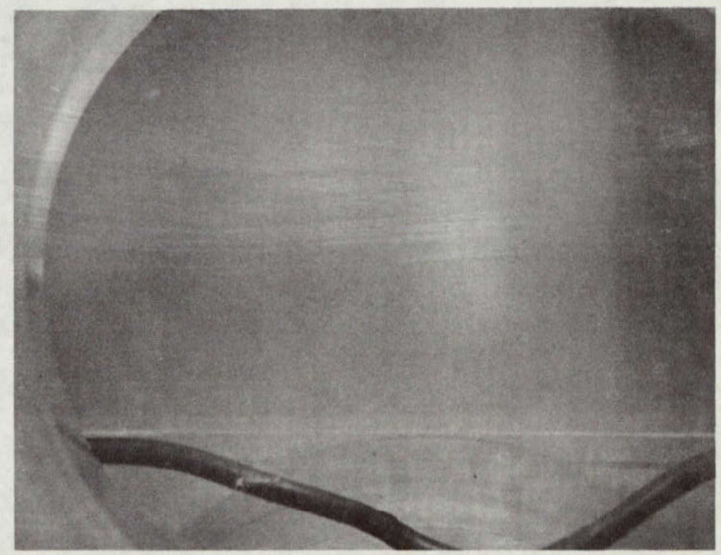


FIGURE 16

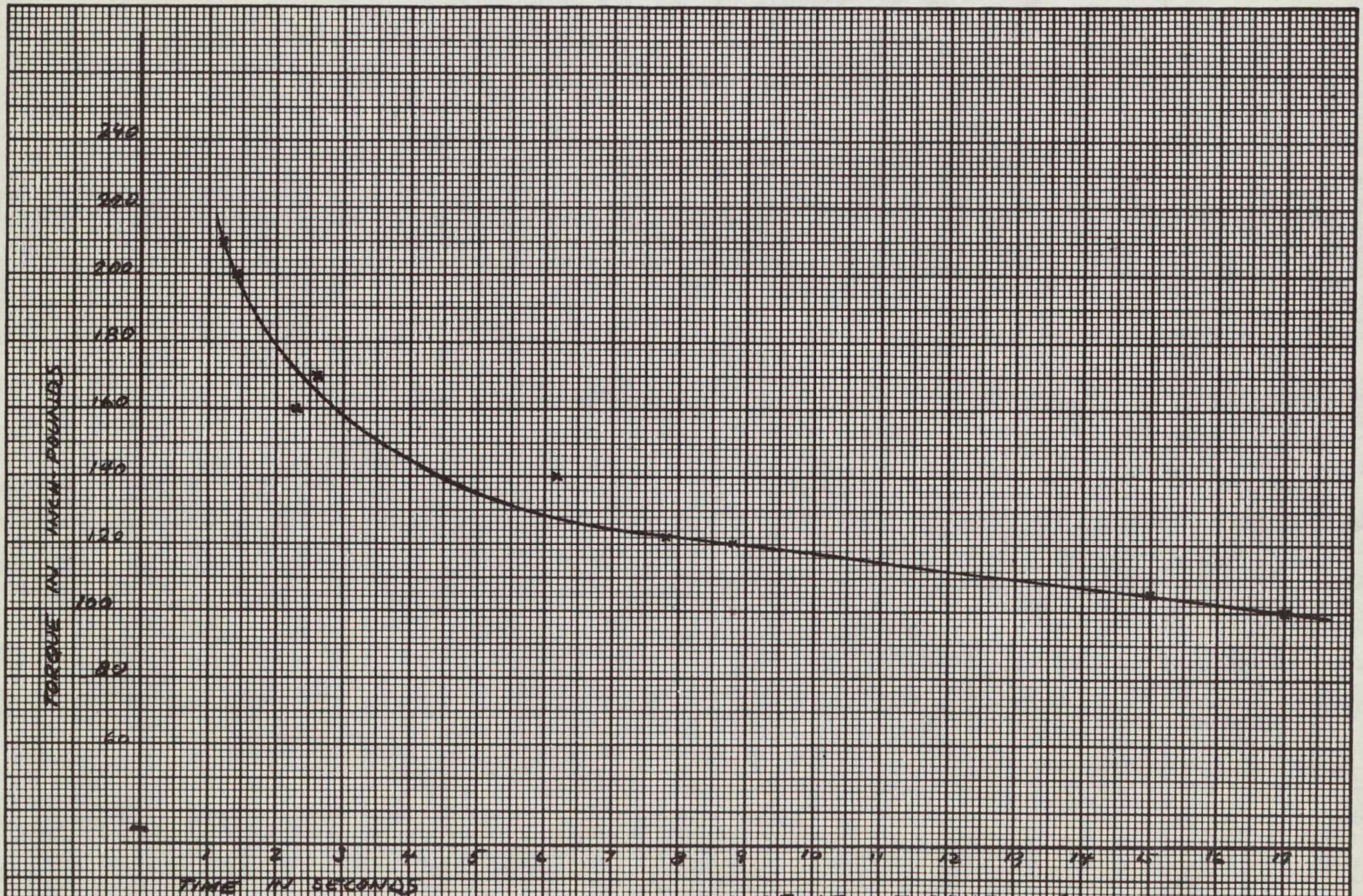


FIGURE 17. - TORQUE REQUIREMENT FOR CONCEPT #3

(b) The piston has a minimum amount of residue when retracted, less than a 1/16 inch thick accumulation over part of the surface.

(c) Cleaning of holes with flush water not different from other concepts.

(d) "O" ring tends to drag and smear some of the material on the surface, which are covered when rotating from vertical to horizontal and vice-versa.

(e) Piston slides down the bore smoothly but smears part of the inlet opening during the initial portion of the return stroke.

(f) Narrow collection band on wall and storage container when material is pushed into container at a slow speed. The width of the band is nearly doubled when the material is pushed in with one fast stroke.

(g) The fast stroke causes uneven distribution, heavy over more than 50% of the area then tapering to a light 25% section of the circular bend. See Figures 18 and 19.

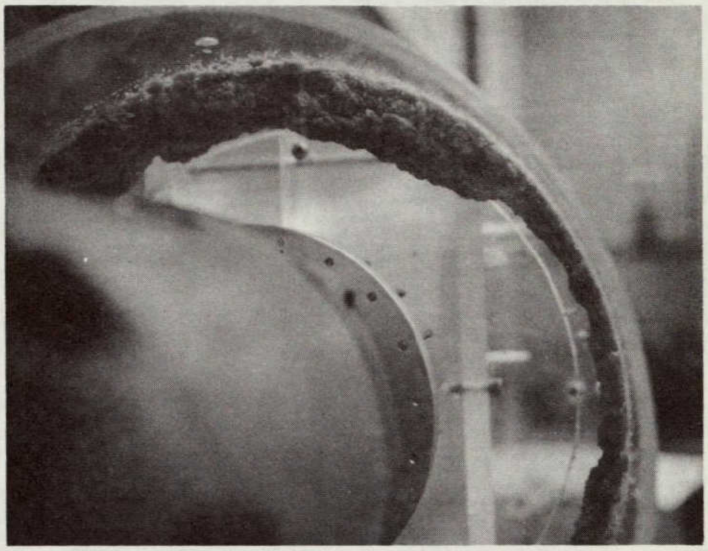


FIGURE 18

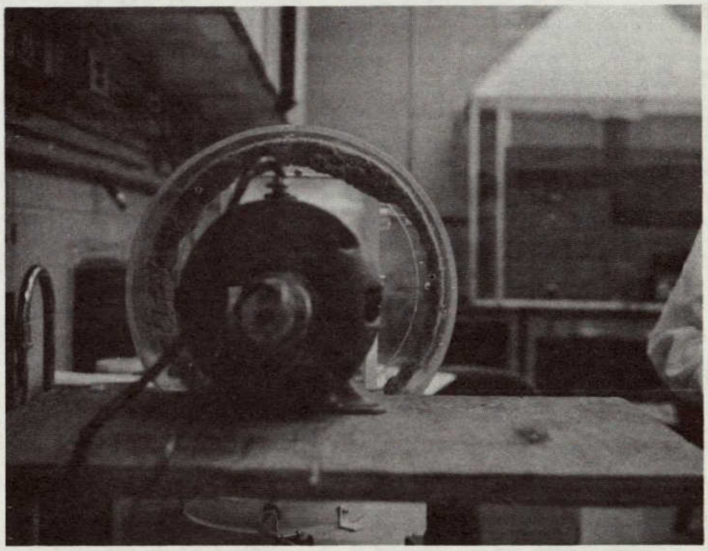


FIGURE 19

4.0 CONCEPT COMPARISON

The tests described in the previous section have provided a preview of the performance and possible problems inherent with each concept for the Modified Hydro John System.

All three concepts are relatively easy to operate, use approximately the same amount of power, occupy approximately the same volume. However, each concept has some definite advantages and disadvantages as can be seen from the analysis shown in Table 1. The disadvantages are limiting only to a degree and can be corrected or minimized by design changes.

The most severe condition occurs in concept #1. The possible progressive accumulation of solid matter at the end of the stroke can cause premature failure. This condition must be corrected in order to keep the applicability of this concept at the same level as the other two. The possible solutions and consequences are shown in Table 2. The analysis shows that the changes required will either affect the present simplicity of concept #1 to a point where it looses the advantages listed in Table 1, or actually transforms it into concept #2.

The comparison is than restricted to concepts #2 and #3.

A review of the disadvantages of concept #2 shows that there are only two significant negatives: the large contamination of surface areas and the less significant limitation on manual operation. These conditions can be limited to a degree by the corrections suggested in Table 3. The reduction of surface contamination to a minimum is important for two reasons. First, most of the sliding surface areas between piston and housing will not be flushed by water or decontaminant. Fecal matter will continue to accumulate to a point where

it would become a microbiological hazard. Second, if the fecal solids were to dry the piston might jam altogether. It is felt that the best correction for this problem is to reduce the relatively large piston to a wiper plate eliminating the auxiliary chamber for the anal flush. See Figure 20. The plate would be retracted for defecation and moved back against the auger end before the anal flush. The advantages of this change are:

1. More flexibility if flushing of the system becomes necessary.
2. It eliminates the air effect noted in section 3.2.2, paragraph 14.
3. Considerable reduction in size and weight.
4. No inaccessible, hidden surfaces where solid matter and bacteria can accumulate.

The only foreseeable disadvantage is that the transition from a round inlet to a square chamber may cause some difficulty in the air and water flow for zero "g" configuration. This condition can be minimized with a smooth, no sharp angles adapter from the seat to the chamber. Another possible effect of the change is that some of the water may be lost to the piston plate. This loss would be negligible and, at the same time, more than sufficient to lubricate the system.

The disadvantages of concept #3 are shown in Table 4. The contamination problem although not as extensive as in concepts #1 and #2 cannot be reduced to the level possible with concept #2. The possibility of air loss and the wear of the "O" rings sealing the interface between the vacuum in the storage container and the cabin ambient make this concept less appealing

than the modified concept #2. It is to be noted that the "0" rings in concept #2 (one on the auger, the others on the valve) are not subjected to as much abuse as in concept #2. The "0" ring on the auger is of small diameter and used in rotary motion only. The ones on the valve are removed with the valve when the storage container is replaced. The "0" ring on the rotating plug of concept #3 instead covers a relatively large surface and must be probably bonded to the grove to prevent its unseating. This condition will considerably affect the drag and consequent wear. These "0" rings are not easily replaceable.

TABLE 1. CONCEPTS COMPARISON

CRITERIUM	CONCEPT #1	CONCEPT #2	CONCEPT #3
1. Power Requirement a) Piston Displacement Force b) Torque (auger or rotating plug) c) Slinger Motor d) Wiper Arm	70 lbs. x 6 inches 20 in/lb x (½ to 1) min. ~10 watts x 1 min. ---	~35 lbs. x 6 inches 8 in/lb x (1 to 2) min. ~10 watts x 1 min. 32 lbs. x 9 inches	<10 lbs. x 12 inches 20 in/lb x 1 min. (equivalent) 10 watts x 1 min. (equivalent)
2. Complexity Compared on basis of moving parts for each concept not including slinger which is common	3 Basic Moving Assemblies 1. Piston 2. Auger 3. Valve	4 Basic Moving Assemblies 1. Piston 2. Auger 3. Valve 4. Wiper	*2 Basic Moving Assemblies 1. Piston 2. Rotating plug *May need an extra remote valve between storage container assembly and vacuum line connection.
3. Weight and Volume	~ Same	~ Same	~ Same
4. Contamination of Piston & Housing Surface Areas	Approximately 500 in^2 of Surface not flushed by wash water	Same as #1	Approximately 200 in^2 of Surfaces not flushed by wash water

TABLE 1. CONCEPTS COMPARISON

CRITERIUM	CONCEPT #1	CONCEPT #2	CONCEPT #3
5. Adaptability to Alternate Solids Processing Methods	Excellent Material can be extruded and piped to any process anywhere in the immediate or near area	Same as #2	Less Adaptable Unless some additional mechanism is added
6. Ease of Installation	Best Minimum fixed volume required. Storage container can be located elsewhere	Nearly as good as #1. Needs a little extra space for wiper mechanism.	Less Flexible because Feces Storage Container must be attached to the unit and in line with the piston.
7. Flexibility of Component Arrangement	Best Partially limited on two sides only.	Good Partially limited on three sides.	Difficult Limited by the long piston on one end and the vertical container at the opposite.
8. Reliability of Operation	Not Good The accumulation of solids at the end of the piston stoke may eventually prevent satisfactory operation due to build up by reducing the length of the storage.	Good The wiper eliminates the accumulation of feces at the end of the piston stroke. The chamber remains relatively clean at all times.	Good Although more sensitive to wear and alignment problems.

TABLE 1. CONCEPTS COMPARISON

CRITERIUM	CONCEPT #1	CONCEPT #2	CONCEPT #3
9. Maintainance	No Problem. Valve gets replaced with every storage container change. Seal between piston and chamber not critical.	Same as #1	Wear and replacement of "O" rings on rotating plug are critical. The "O" rings form the seal between storage container vacuum and cabin ambient.
10. Loss of Cabin Air	A minimum amount of air is expected to leak into evacuated storage container. This may be minimized by proper timing of the valve between auger and container.	Same as #2	Considerable amount of air will leak into storage container during each usage. Maximum loss = volume of storage container.
11. Possibility of Manual Operation	Very difficult, if possible, depending on type of failure.	Same as #2	Good It is possible to operate the plug and or piston manually and continue using until repairs are made.
12. Ease of Fabrication	Easiest	Slightly more complex than #1 because of additional piston and wiper.	Apparently easy, however, it requires more careful design, and more complex and critical machining.

TABLE 2. ANALYSIS OF CONCEPT #1

NEGATIVE FEATURE	POSSIBLE CORRECTION	CONSEQUENCE	
Accumulation of solids at end of piston travel due to relatively small auger inlet opening	(a) Use a larger auger with a minimum inlet opening as wide as the moving piston	A large dead collection volume inside of auger may require several usages before solids deposited into auger are pumped into outlet tube	The accumulation of solids on the face of the traveling piston will probably remain unchanged
	(b) Use several small augers side by side, turning on a common drive	Offers better packaging arrangement and less dead volume but more complex than adding a plain wiper as in Concept #2.	
	(c) Use wiper	This change which seems to be the easiest is what makes Concept #1 into Concept #2.	
Manual operation	Same as Concept#2	Same as Concept #2	

TABLE 3. ANALYSIS OF CONCEPT #2

NEGATIVE FEATURE	POSSIBLE CORRECTION	CONSEQUENCE
Large contamination surface	(a) Remove most of the four sides of piston so that only front plate and cylindrical anal flush receptacle ride against housing	No mechanical problem. It will create a microbiologically unsafe accumulation of feces over a period of time.
	(b) Replace entire piston with a moving plate. Plate may be moved (return stroke) during the anal flush thus allowing partial washing of contaminated surface	(a) It will reduce size of system. (b) It may create a water flow problem for zero "g" operation. (c) Some water may be lost to the feces container.
Manual operation	(a) Make design as simple as possible allowing quick disconnect and repair of any critical part.	No problem
	(b) Make adapter to storage container so that it may be used directly as a Dry John while repairing the rest of the system.	Such a design although desirable would require careful planning and execution.
	(c) Use emergency Apollo-type plastic bag devices.	Simple but psychologically unappealing.

TABLE 4. ANALYSIS OF CONCEPT #3

NEGATIVE FEATURES	POSSIBLE CORRECTION	CONSEQUENCE
Air loss	Add valve between container and rotating plug	Increased complexity. Increased length of stroke for displacement piston. The valve with a 4" orifice would either be relatively unmanageable (if a ball valve) or not too reliable (if a gate type valve) for the application.
Contamination	Can be minimized by removing most of the cylindrical wall on the rotating plug. The rotating plug could be reduced to a cylinder pivoted from vertical to horizontal.	Even though this change would considerably reduce the surfaces wetted by the fecal solids, there would still remain remote surface where solids could accumulate, dry and possibly cause the system to fail.
Not readily adaptable to alternate feces process such as remote disposal	Remove feces from piston by mechanism other than slinger to continue pumping downstream.	It would complicate the system to a degree where it would be a rearrangement of Concept #2 and probably not as good.
Wear and replacement of "O" rings on rotating plug	No correction available. Condition could be alleviated considerably by a local water or disinfectant spray to lubricate the system.	The removal of the spray liquid may cause additional complication in zero "g" environment.

5. CONCLUSION

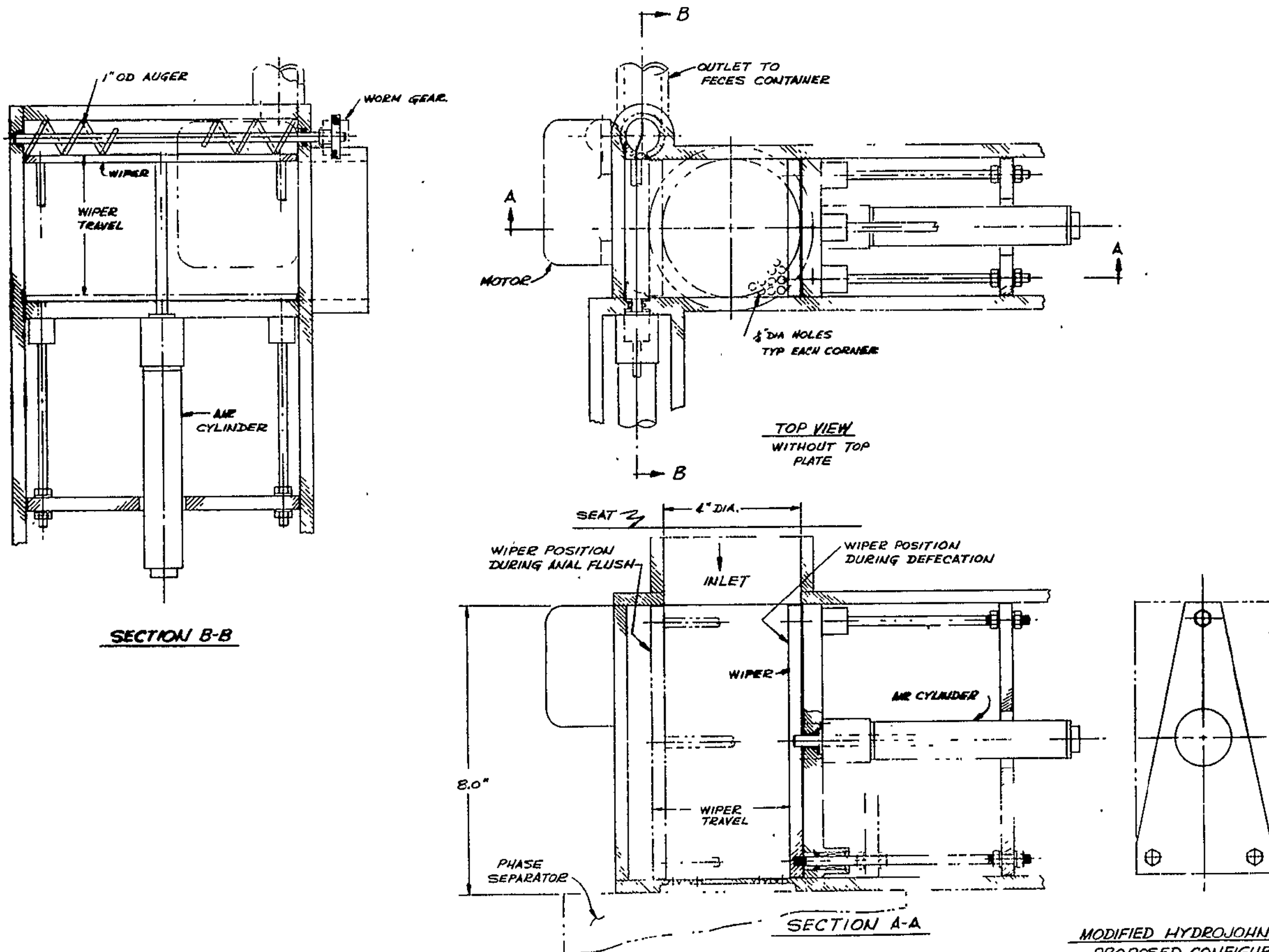
It is recommended that the modified concept #2, shown in Figure 20, be used for the Modified Hydro John program.

It is relatively simple and can be readily fabricated. The concept also allows for extensive use of transparent material such as plexiglas where it is desirable to monitor the performance of the system without disassembly. It is rather superfluous to point out that disassembly of a system such as this is rather "messy". The psychological objections and the microbiological hazard require that any exposure of the internal surfaces of the system be carefully controlled. For this reason it is necessary to avoid design features and components which require access to the internal surfaces of the unit such as would be required to replace the "O" rings in the rotating plug of concept #3.

In the final design the Modified Hydro John would consist then of a nearly rectangular chamber with the seat, anal flush and warm air flow adapter at the top, and a perforated bottom connecting to the water-air phase separator. The chamber has two moving parts: a wiper plate to move the stool across and to the end of the chamber and a side wiper to feed the stool into the auger. Both wipers are in the extended position at all time except during usage of the equipment. After the user places himself on the seat both wipers are pulled back in that the auger is exposed. After defecation the wiper plate and the side wiper are energized in sequence, followed by the anal flush. The wipers remain in place until

next usage. If required, it may be possible to automatically retract the wiper plate during the anal flush to allow the plate to be rinsed.

The opening of the solenoid valve between the storage container and the auger, and the rotation of the auger are coordinated to start with the motion of wiper plates and to end at a preselected, fixed time, e.g. one minute after the end of the travel of the wipers. This should compensate for the time delay noted in section 3.2.1, paragraph 7. The chamber will be covered externally, above the seat, at all times, and an air flow in excess of 10 CFM will be provided automatically as soon as the cover is lifted for usage and during usage to avoid bacterial contamination to the surroundings.



MODIFIED HYDROJOHN
PROPOSED CONFIGURATION
SCALE - FULL SIZE

FIGURE 20

GENERAL ELECTRIC

SPACE DIVISION

SPACE SYSTEMS ORGANIZATION